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# SHRINKAGE LOSSES IN ALBERTA HOG DELIVERIES

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Shrinkage Losses in Alberta Hog Deliveries submitted by Robert James Tchir in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Economics.

ABSTRACT

It has been traditionally suggested that most sectors of the agricultural economy are comprised of highly competitive businesses, where even a narrow margin of cost can mean the difference between success or failure. The Alberta hog industry is no exception, and the entire industry can potentially benefit from any reduction in the producer's cost margin.

One of the areas which has not received full attention in Alberta has been that of tissue shrinkage in hog deliveries, which can be considered as a function of operational efficiency. If hogs are not sent to slaughter in the shortest possible time, using the smoothest possible handling techniques, and subjected to optimal feeding or watering methods, hogs may lose several pounds of carcass weight by the time they are graded. Because producers are paid on a carcass weight basis, they stand to lose money through tissue shrink which might possibly have been avoided.

The work reported in this thesis attempted to determine if and how a number of operational variables affect carcass yield and presumably tissue shrink, and transform these effects into dollar values using econometric analysis techniques. In one part of the study several factors were shown to significantly affect carcass yields. The most significant factor was time from arrival at the plant to time of slaughter. Comparing hogs subjected to immediate slaughter with hogs subjected to 24 and 48 hour delayed kills, carcasses lost an estimated 1.6 and 3.0 percent of their weight during the first and second days, respectively. Other significant factors found to affect carcass yield were the amount of

finish (fatness) on hogs, the degree of stress to which the hogs were subjected during handling, the air temperature, and whether or not water was available to the hogs up to the time of slaughter. Finally, cost effects of each variable were quantified, and a cost-approximating equation was derived.

By minimizing tissue shrinkage, the potential for gain to the Alberta hog industry may reach into the million dollar per year range.

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First, I wish to thank Dr. M.H. Hawkins for his personal interest, guidance and support throughout the course of this study. Both Dr. Hawkins and Mr. John Prentice deserve additional credit for conceiving and initiating this project.

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All persons associated with the Alberta Hog Producers Marketing Board deserve credit for their contributions to this study. In particular, special thanks are extended to Mr. Ed Schultz, Mr. Stan Price, Mr. Lloyd Unterschultz, Mr. Ron Landry, Mr. Jim Coughlin and Mr. Gary MacMillan, who all made personal contributions toward the completion of this study through their association with the Hog Board.

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Special thanks go to Dr. Bruce Jeffery, who helped encourage the development of this project, and to Alberta Agriculture, whose generous funding made this project possible.

Finally, my deepest gratitude goes to my wife, Chris, not only

for the long hours spent in the typing of this thesis, but for her continuous and loving support throughout the duration of this work. In return for her support and encouragement, I dedicate this work to my wife, Chris.

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# CHAPTER I

# INTRODUCTION

## Background of the Problem

Efficiency in marketing is considered to be a function of two contributing entities, one being the concept of operational efficiency, and the other being that of pricing efficiency.[1] Williams and Stout clarify this distinction, by describing operational efficiency as "all of the adjustments that might be made by individual firms, both in the short run and the long run, to reduce per unit costs"[2], and pricing efficiency as a measure of "performance of the marketing system in establishing equitable prices and values and in providing services that prices in a free society are expected to supply."[3]

It is the intent of this study to investigate as many facets of operational efficiency in Alberta hog deliveries as possible, to determine whether or not losses are minimized throughout all systems of hog marketing in Alberta. In particular, place utility and time utility will be considered, because of their inherent relationship to the deli-

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1 Richard L. Kohls and W. David Downey, Marketing of Agricultural Products, 4th ed. (Toronto: Collier-Macmillan Canada, Ltd., 1972), p. 11.

2 Willard F. Williams and Thomas T. Stout, Economics of the Livestock-Meat Industry (New York: The Macmillan Company, 1964), p. 139.

3 Ibid., p. 121.

very system and their influence upon costs.[1]

If costs of inefficient hog deliveries and handling methods can be isolated and quantified, producers will benefit from this knowledge because they would subsequently have a basis upon which they could make adjustments in their marketing programs to accomodate the situation.

This study will concentrate on the problems of tissue shrink and related losses in Alberta hog deliveries. Tissue shrink in hogs is a physiological function which progresses at various rates when hogs are subjected to confinement from feed and water. In a marketing context, "tissue shrink is the loss in weight of the hog's carcass between the time it is loaded and the time it is slaughtered."[2]

Two other types of weight loss in marketing of livestock are acknowledged in various studies. One type is excretory shrink which "is due to the elimination of waste materials from the animal's body while it is in transit."[3] A third type is cooler shrink, which is the weight loss incurred by a carcass during the post-slaughter refrigeration period.

Currently, Alberta hog producers sell their hogs on a carcass

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[1] Richard L. Kohls and W. David Downey, Marketing of Agricultural Products, p. 5; Theodore N. Beckman, William R. Davidson and W. Wayne Talaryzk, Marketing, 9th ed. (New York: The Ronald Press Company, 1973), p. 38.

[2] Richard D. Gibb, "Hog Shrinkage", Research in Agriculture, vol. 40 (October 1961), p. 2.

[3] Ibid., p. 1.

grade basis, using an index of weight, backfat, and quality demerits to adjust prices.[1] The grading is done on a hot carcass weight basis, at the end of the kill line prior to entering the cooler. Therefore, when it loses weight through tissue shrink, a carcass returns less to its producer than an unshrunk carcass. Thus, "it is therefore the producer, rather than the packer, who becomes concerned about the time and distance involved in delivering livestock to the killing floor, about weekend holdovers, and about assorted other considerations related to transportation of livestock."[2]

Presently, a delayed kill penalty is imposed upon packing plants which do not slaughter hogs by the day after delivery. However, this means that hogs may theoretically be held for as long as two days (i.e. day of delivery, next day until slaughter) without any compensation to producer for shrink losses. Furthermore the amount of compensation paid out for shrink on hogs held longer than this period may not reflect the amount of losses actually incurred by a producer.

Some of the overall shrink loss will be unavoidable due to the essential functions of assembling, shipping and holding of hogs. However, if the time spent in performing these functions of marketing is not minimized (within limits of cost) shrinkage due to excessive

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[1] Murray H. Hawkins, et al., Development and Operation of the Alberta Hog Producers Marketing Board, Rural Sociology Bulletin 12, 3rd ed. rev. (Edmonton: The University of Alberta, Department of Extension, March 1977).; Canadian Pork Council, The Canadian Hog Carcass Grading/Settlement System (Ottawa: The Canadian Pork Council, 1977).

[2] Willard F. Williams and Thomas T. Stout, Economics of the Livestock-Meat Industry, p. 702.

delays or mishandling of hogs will lead to unwarranted producer losses. Williams and Stout suggested that time in transit from farm to slaughter is the single most important factor in livestock shrinkage. Because of the effects of this time factor, in conjunction with "excitement and confinement off feed and water, it obviously is desirable to minimize the total time involved and, to the extent possible, avoid abnormal marketing conditions."[1]

## Objectives of the Study

The objectives of this study were:

(1) to quantify the extent of the influence of various external or environmental factors upon rates of shrink, by means of a detailed investigation under controlled conditions. (The specific factors, or variables, are detailed in the hypotheses);

(2) to determine what the effects of these factors mean to hog producers in economic terms;

(3) to isolate specific problem areas in hog deliveries by examining a cross section of large scale, long-distance hog shipments in the province, and comparing the results of these shipments with the results of the controlled experiment;

(4) to provide an empirical basis upon which producers would be able to make decision between alternative delivery methods or handling techniques;

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[1] Ibid., p. 655.

(5) to provide an empirical basis on which policy recommendations could be made and to provide the tools for future policy decisions in the area of handling and delivery of hogs.

The objectives as listed above gain increased importance to the producer under the current carcass weight/index settlement system. Since the producer bears much of the risk involved in the handling and delivery of hogs, "his responsibility and his concern extend over a much greater portion of the marketing process."[1] Thus, under the given constraints for pricing efficiency, the opportunity for gain shifts to the area of operational efficiency, which is the principal area of concern in this study.

## Hypotheses

(1) $H_0$ = There is no significant relationship between tissue shrink and the time span from arrival at the plant to slaughter.

$H_1$ = There is a significant relationship between tissue shrink and the time span from arrival at the plant to slaughter.

(2) $H_0$ = There is no significant relationship between tissue shrink and transit time (or distance shipped).

$H_1$ = There is a significant relationship between tissue shrink and transit time (or distance shipped).

(3) $H_0$ = There is no significant change in the rate of shrink over time.

$H_1$ = Tissue shrink increases with a non-linear relationship to time.

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[1] Ibid., p. 702

(4) $H_0$ = The rate of shrink is not significantly different for lighter weight hogs than for heavier hogs.

$H_1$ = There is a significant relationship between the weight of hogs and the rate of shrink.

(5) $H_0$ = There is no significant relationship between rates of shrink and the fatness of hogs.

$H_1$ = There is a significant relationship between rates of shrink and the fatness of hogs.

(6) $H_0$ = Rates of tissue shrink are not significantly related to air temperatures.

$H_1$ = Rates of shrink are significantly related to air temperatures.

(7) $H_0$ = Rates of tissue shrink are not significantly different for hogs fed just prior to shipment than for hogs which have been confined from feed for some time period prior to shipment.

$H_1$ = There is a significant relationship between rates of tissue shrink and the amount of time hogs are off feed prior to shipment.

(8) $H_0$ = There is no significant relationship between rates of shrink for densely loaded hogs on a truck and less densely loaded hogs on a truck.

$H_1$ = There is a significant relationship between the rate of shrink and the on-truck density of a load of hogs.

(9) $H_0$ = There is no significant relationship between rates of shrink and levels of handling stress.

$H_1$ = There is a significant relationship between rates of shrink and levels of handling stress.

## Sources of Data

Data collected in the course of this study was of a primary nature. First, liveweights of hogs were obtained at A.H.P.M.B.[1] assembly yard scales. Producer information was obtained either through interviews over the telephone prior to producer deliveries, or directly from the producers as loads of hogs were delivered to the assembly yards. The carcass weights and backfat measures were subsequently taken from grader's reports. Daily air temperatures for Red Deer were taken from records kept by the Department of Meteorology at The University of Alberta.

## Procedure

This study was carried out in two main phases. The first phase involved detailed observations of hog shipments to the A.H.P.M.B. assembly station at Red Deer, Alberta. Handling methods were closely observed, and hogs were held over for varying time periods to simulate at-plant holding. These hogs were subsequently slaughtered at Fletcher's plant which is located next to the assembly yard.

In the second phase of this study, records were kept for larger assembled lots of hogs which were shipped from Lethbridge and Calgary to Edmonton and Red Deer. Liveweights were recorded as hogs arrived at the assembly yards and at the plants. Carcass weights, backfat measures, and indexes were taken from hog board records, in order to determine yields which could be compared with those in phase 1.

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[1] A.H.P.M.B. is the Alberta Hog Producers Marketing Board.

All recorded data were analysed to determine effects of specific variables upon shrink. Comparisons were made among different producers and different shipments.

## Outline of Chapters

Chapter II, A Review of Related Studies, examines some previous studies of shrinkage in hog and livestock transportation. A discussion of methodologies and variables studied is provided.

Chapter III, Current Marketing Practices and Their Relevance to Shrinkage, discusses the possible marketing alternatives currently available to hog producers in Alberta. The potential effects of various practices upon shrink are described.

Chapter IV, Methodology, explains how the study was structured, how data were collected, and methods for treatment of the data. Some of the problems encountered in the course of the study are reviewed at the end of the chapter.

Chapter V, Analysis, provides details of the analytical procedures used to test the hypotheses, and results of the regression analysis.

Finally, Chapter VI, Conclusions and Recommendations, draws conclusions on the hypotheses, provides a quantitative description of how shrinkage factors can affect returns to producers, and makes some recommendations as to how losses can be reduced through modifications in marketing programs.

# CHAPTER II

## A REVIEW OF RELATED STUDIES

A number of previous studies have been conducted to examine shrinkage in marketing of hogs and other livestock. The basic objective in most of these studies has been to determine the degree of relationship between shrinkage and an assortment of variables associated with shrinkage. Total liveweight shrink was investigated in some of the research, while other studies looked at tissue shrink by using comparisons with carcass yields.

A 1938 U.S.D.A. study conducted by Bjorka[1] attempted to distinguish tissue shrink from excretory shrink, by assuming that "loss in weight resulting from tissue shrinkage represents an actual reduction in carcass weight and also reduces the dressing percentage based on purchased weight."[2] So for two similar hogs subjected to similar feeding methods but handled under different conditions, it could be assumed that any difference in yield can be equated to the difference in tissue shrink created by the varying conditions.

Exogenous variables in Bjorka's study were: time in transit, liveweight, seasonality, and the source of purchase ( i.e. direct purchases versus public markets). Conclusions of this research showed that:

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[1] Knute Bjorka, Shrinkage and Dressing Yields of Hogs, Technical Bulletin No. 621 (Washington, D.C.: U.S. Department of Agriculture, June 1938).

[2] *Ibid*., p. 1.

tissue shrink was continuous throughout the entire period of transit, heavy hogs tended to have higher yields than lighter hogs, and shrinkage was less in winter than in summer.[1]

Most of the subsequent research on livestock shrinkage has concentrated on the problem of liveweight shrink (the sum of excretory and tissue shrinkage). Such research was justified at the time it was done because most producers were paid for their hogs on a liveweight basis, and thus liveweight shrink was the producers' primary concern (whereas tissue shrink was of more importance to the packers).

For example, a 1954 study by Clifton, Jessen and Jacobs[2] was concerned with total weight changes in hogs using different grades, different commission firms (i.e. effects of different feeding methods) and different days, as variables. Regression and other statistical tests were used in the analysis, but no statistically significant relationships were found to exist with those particular variables.

In 1960, a study by Stout and Armstrong of Purdue University provided an analysis of both total shrink and tissue shrink, and discussed the relationship between these measurements.[3] Long distance shipments (100, 200 and 600 miles) were examined and various feeding methods were analysed to determine the effects on total shrink and yield.

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[1] Ibid., p. 15.

[2] E.S. Clifton, R.J. Jessen and E.M. Jacobs, "Amount and Source of Shrink and Fill in Marketed Hogs", Journal of Farm Economics, Vol. 36, No. 4 (November 1954), pp. 688-692.

[3] Thomas T. Stout and Jack H. Armstrong, Shrink and Yield in Market-Fed Hogs, Research Bulletin No. 710 (Lafayette, Ind: Purdue University, Department of Agricultural Economics, December 1960).

A number of other variables were closely controlled in this study because it was assumed that they would have some effects upon shrinkage. In addition to control of distances shipped, methods of transportation, time in transit, percent load capacity, liveweights of animals, time last fed, air temperatures, and ratios of barrows to gilts were maintained at constant levels.

Several conclusions were drawn from the effects of different feed diets and feeding times upon shrinkage. In addition, it was concluded that in that particular study, "tissue shrink is always inversely related to yield, rising as yield decreases, and falling to negative values as yield increases over distance."[1] In summary, the major implication of this study is that a strong relationship exists between yield and tissue shrink.

In April, 1959, the Western Livestock Marketing Research Technical Committee published several articles on shrinkage.[2] Although these studies examined shrinkage in cattle, some of the research and the recommendations might be applied to hog marketing. Several of the conclusions reflect the results of studies which tested hogs. For example, it was concluded that time in transit has the greatest effect on shrink, and that air temperatures affect rates of shrink.[3]

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[1] Ibid., p. 5.

[2] Clive R. Harston, Shrinkage is Important, Circular 220: Shrinkage Depends on Where, When and What You Market, Circular 221: Shrinkage Depends on How You Market, Circular 222 (Bozeman: Montana State College, April 1959).

[3] Ibid., No. 221.

Other conclusions of this study were that:

(1) Although there are differences in shrink rates according to sex of cattle, these differences become very difficult to predict under variable conditions.[1]

(2) There is very little difference in rates of shrink between different breeds of cattle.[1]

(3) Shrinkage occurs at slower rates for fatter cattle, and finish will have a greater influence upon shrinkage than absolute weight.[1]

(4) Different handling methods will vary the amount of shrink. Conditions to be avoided include overcrowding on trucks, unusual (or extreme) weather conditions, and "overfeeding" prior to shipment.[2] It was suggested that it is not unusual for cattle on short distance hauls to shrink more than cattle on long distance hauls because on long hauls many of these adverse conditions are avoided by careful handling methods.[3]

Weight loss in beef cattle, hogs and lambs from farm to the first market was examined by Henning and Thomas in a 1962 study.[4] Livestock were weighed at the farm using portable scales, then weighed

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[1] _Ibid._, No. 221.

[2] _Ibid._, No. 220.

[3] _Ibid._, No. 221, p. 5

[4] G. F. Henning and P.R. Thomas, _Some of the Factors Influencing the Shrinkage of Livestock From the Farm to the First Market_, Research Bulletin 925 (Wooster: Ohio Agricultural Experiment Station, October 1962).

upon arrival at the market. Data regarding environmental conditions, handling methods, feeding methods, distance, sex, and time in transit were also collected.

Analysis was done using regression and correlation techniques. Appendix A shows some graphs of the resultant linear regressions.

Henning and Thomas also discussed the effects of tranquilizing cattle, and the use of sprinkler systems on truckloads of hogs in hot weather.[1] The results from tranquilizing cattle proved to be inconclusive. Any differences in results were attributed to "the individual variations inherent among animals."[2] When tested during temperatures over 77°F (25°C), sprinkler systems on trucks were found to significantly reduce deaths and shrinkage for hogs on 11 and 27 hour shipments, but not on 5 hour (or less) shipments.

Richard D. Gibb studied the effects of six variables on hog shrinkage: feeding sugar in water prior to shipment, feeding of high and low protein diets, distance shipped, temperature, truck speed, and weight of animals.[3] Results of Gibb's study are summarized in Appendix B.

In studying tissue shrink, Gibb made an assumption which is part of the basis for the methodology of this thesis: "If a random sample of two large groups of (say 1,000 each) hogs is obtained and if

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[1] Henning and Thomas, Factors Influencing Shrinkage, p. 39, citing Russell H. Hinds and Robert F. Guilfoy, Jr., Sprinkling Hogs in Trucks to Reduce Losses From Heat, U.S. Agricultural Marketing Research Report No. 374 (Washington: U.S.D.A., November 1959).

[2] Henning and Thomas, Factors Influencing Shrinkage, p. 13.

[3] Richard D. Gibb, "Hog Shrinkage", Research in Agriculture, Bulletin 40, No. 5 (Macombe: Western Illinois University, October 1961).

these two groups average 210 lbs. live at the beginning of the test, one could logically assume that their carcasses also weighed the same at the beginning of the test. If the carcasses do not weigh the same at slaughter time, we can safely assume that one group has experienced more tissue shrinkage than the other.

Under Gibb's restrictive conditions, the assumptions appear to be valid. However, if conditions vary from the restrictions stated, the assumptions would have to be modified. Yields may change from carcass to carcass, and as number of hogs tested become smaller and less random, the factors influencing yields must be accounted for.

One factor which could influence yield is the liveweight of the animal. Richmond and Berg showed that a linear relationship exists between carcass weight and liveweight,[2] as did D.M. Smith in 1954.[3] This implies that there would be a relationship between yield and weight of the animal. Richmond and Berg showed weight to have a direct influence on fatness; for 73 hogs studied, "bone grew relatively slowly while muscle had a relatively high growth rate. The decline in muscle growth after 91 kg liveweight was offset by the increase in fat deposition."[2] From these results, it might be concluded that liveweight influences fatness, which in turn influences yield.

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[1] Ibid., p. 2.

[2] R.J. Richmond and R.T. Berg, "Tissue Development in Swine as Influenced by Liveweight, Breed, Sex and Ration", Canadian Journal of Animal Science, Vol. 51, No. 1 (April 1971), p. 33.

[3] D.M. Smith, "The Relationship Between Liveweight and Carcass Weight Increments of Pigs", New Zealand Journal of Science and Technology, Agriculture, Vol. 38 (1957), pp. 803 - 806.

Feeding can have significant effects upon carcass yields, although a distinction must be drawn between feeding methods (feed restriction levels) and feed diets. Flipot and Roy showed that the type of feed restriction used does significantly affect dressing percentage, primarily because of effects on fatness.[1]

J.P. Bowland and R.T. Berg studied effects of feed rations (low-energy versus high-energy) and found that this factor significantly affects dressing percentages, once again because of the effects on fatness.

Bowland and Berg also found that in some cases, breed of hog affected dressing percentage, while in other cases it did not.[3] However, Flipot and Roy showed that in their study breed did significantly affect dressing percentage.[1] Although these results appear to be in conflict, differences may have been due to similarities among specific breeds or mixtures of breeds.

Sex of hogs apparently does not significantly affect dressing percentages, according to Flipot and Roy[1] as well as Bowland and Berg[2]. And, in addition to not affecting yield, sex does not affect shrink rates, according to Henning and Thomas.[3]

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[1] P. Flipot and G.L. Roy, "Effets des Methodes de Rationnement sur les Performances et al Qualite des Carcasses des porcs de Marche", Canadian Journal of Animal Science, Vol. 56, No. 2 (June 1976), p. 347.

[2] J.P. Bowland and R.T. Berg, "Influence of Strain and Sex on the Relationship of Protein to Energy in the Rations of Growing and Finishing Bacon Pigs", Canadian Journal of Animal Science, Vol. 39, No. 1 (June 1959).

[3] Henning and Thomas, Factors Influencing Shrinkage, p. 31.

From the preceding literature, Table 2-1 was derived. It shows factors which affect both yield and/or shrinkage, and their significance.

Table 2-1

FACTORS INFLUENCING YIELD AND/OR SHRINKAGE

| Factors | Yield | Shrink |
|---|---|---|
| Feed Restriction | Sig. | Sig. |
| Feed Ration | Sig. | Not Sig. |
| Sex | Not Sig. | Not Sig. |
| Breed | Sig. | Not Sig. |
| Finish | Sig. | Sig. |
| Liveweight | Not Sig | Sig. |

The following list summarizes the variables which have been found to have statistically significant effects on shrinkage in a variety of previous studies:

(1) Time (from farm to slaughter),

(2) Liveweight of hogs,

(3) Seasonality,

(4) Temperature and/or climatic conditions,

(5) Distance shipped,

(6) Feeding methods,

(7) Conditions on truck,

(8) Methods of handling,

(9) Finish,

(10) Source of purchase (e.g. direct deliveries as compared to assembled lots).

In studying source of purchase as a variable differences in shrink were found to exist; however, feeding practices tended to differ between sources of purchase, which may have been the actual reasons for these differences.

Of all the variables in the preceding list, time from farm to slaughter is generally considered to have the strongest effect on shrink. However, the time variable is closely associated with time off feed and water, with some amplification due to the added levels of stress and excitement.

In this study, all these variables were considered, with the exception of seasonality. Variables found to be non-significant in previous studies were not included in this study.

CHAPTER III

# CURRENT MARKETING PRACTICES AND THEIR RELEVANCE TO SHRINKAGE

## Marketing Alternatives and Operational Efficiency

In understanding the economic ramifications of tissue shrinkage, a discussion of its relationship with operational efficiency may provide some insight. For example, Harold Breimyer has stated that operational efficiency is a consideration of "how well the physical part of marketing is done - the quantity and quality of services performed relative to resources used."[1] In the context of the marketing alternatives discussed in this chapter, Warrack carries the definition a bit further: "The focus [of operational efficiency] is on the physical marketing functions of assembly, processing, storage, and transportation."[2] Shrinkage is also a cost factor in processing when one considers costs of cooler shrink to the meat packer.

If costs of shrinkage are embodied in these functions, it becomes the producer's responsibility when designing a marketing program, to not only provide an optimum flow between functions, but to consider shrinkage as a factor within the framework of these functions.

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[1] Harold F. Breimyer, Economics of the Product Markets of Agriculture (Ames: Iowa State University Press, 1976), p. 125.

[2] Allan A. Warrack, "A Conceptual Framework for Analysis of Marketing Efficiency", Canadian Journal of Agricultural Economics, Vol. 20, No. 3, November 1972, p. 11.

## Transport Alternatives

In Alberta, hog producers have several potential alternatives for moving hogs to market. The producers may deliver hogs directly to packers or Board marketing terminals[1] using their own trucks, or by hiring a trucker. (Some truckers actually work as trucker-assemblers, by picking up several groups of hogs at different farms to form a single large load). Alternatively, hogs could be delivered to local assembly yards where larger lots are subsequently shipped to Board terminals or directly to packers.[2] Thus, producers do have some degree of flexibility in planning how to ship their hogs. "Board marketing terminal location, convenience and lot size will be considered by hog producers in choosing the flow that will give them the most efficient mechanism for moving their hogs."[3] Alternative patterns of moving hogs from farm to slaughter are shown in Figure 3-1.

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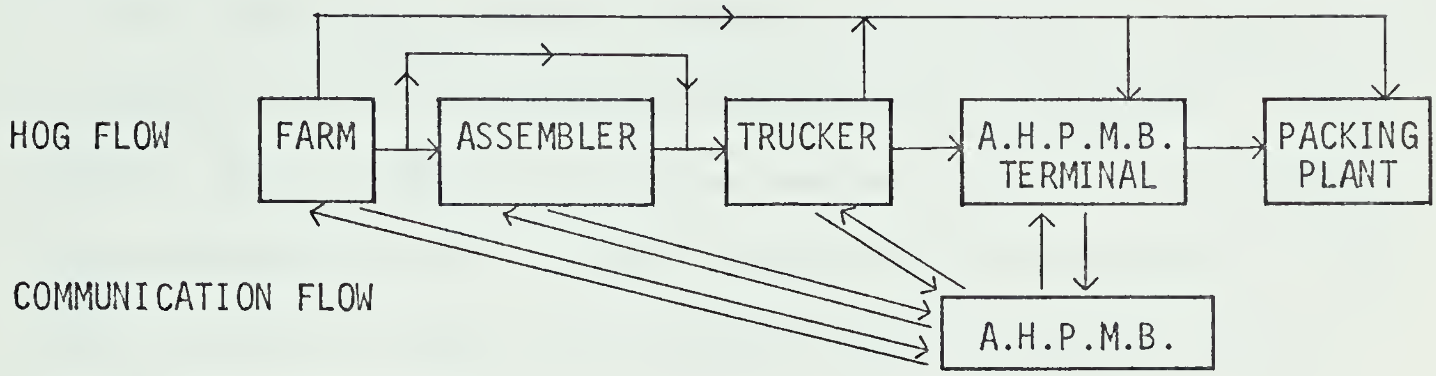
[1] The term "marketing terminal" is used by the A.H.P.M.B. in reference to the Board-operated assembly yards. There are currently six A.H.P.M.B. marketing terminals in Alberta. These serve as major assembly points for both export and domestic hogs. Terminals are located at Lethbridge, Calgary, Red Deer, Edmonton, Vermilion and Grande Prairie.

[2] Alberta Hog Producers Marketing Board, "Proposed Changes to Alberta's Hog Marketing System", Alberta Hog Journal, Vol. 4, No. 1 (Winter, 1975), p. 33.

[3] Ibid., p. 35.

Figure 3-1

HOG FLOW AND COMMUNICATION FLOW PATTERNS




Source: Lloyd Unterschultz, "New Hog Marketing System", Alberta Hog Journal, Vol. 4, No. 1 (Winter 1975), p. 30.

Given other cost criteria for shipping hogs, shrink losses should also be considered by producers when comparing the costs of these alternatives. This study examines two of the more commonly used alternatives: shipments direct to plant, and shipments assembled at several of the Board terminals.

## Alternative Handling Methods

A number of different techniques are used in the handling of hogs from the farm gate to the packing plant. For example, there are several ways in which hogs can be loaded onto a truck, and each method will affect the levels of stress and excitement experienced by the hogs. Some producers might use electric prods to move hogs, while others use slappers, or a large board to push hogs along when loading. Some hogs are forced up an inclined ramp while others might be loaded using a level loading chute.

In a discussion of death losses of Alberta hogs in transit (due to PSS)[1], Strokappe makes a number of recommendations to producers in order that stress-inducing situations are minimized. According to Strokappe, some of the handling practices to be avoided are: use of electric prods, shipments during hot weather, forcing of hogs through narrow openings or onto strange flooring, and moving indoor hogs into bright sunlight, because such practices tend to increase levels of stress and excitement.[2]

J.R. Thompson makes similar recommendations in a study of PSE or DFD pork.[3] He warns against crowding of animals, feeding high sugar rations prior to shipping, and marketing during hot weather. He also says that "excessive *ante mortem* exercise or handling may induce rapid rates of carcass metabolism . . .".

Because these handling methods tend to increase levels of stress and metabolism in animals, rates of tissue shrink should consequently increase. Harston supports this concept: "Loading, unloading, jostling about in a moving truck or rail car, change of environment, and different handlers produce nervous disturbances [or stress] in the

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[1] PSS is Porcine Stress Syndrome: see John H. Strokappe, "Transport Loss Research Report No. 1", <u>Alberta Hog Journal</u> Vol. 7, No. 1 (Winter 1978), p. 24. ; John H. Strokappe, "Transport Losses in Alberta", <u>Alberta Hog Journal</u> Vol. 7, No. 3 (Summer 1978), pp. 31, 32.

[2] Strokappe, "Transport Losses in Alberta", p. 32.

[3] PSE is Pale, Soft, Exudative pork, DFD is Dark, Firm and Dry pork. These conditions are associated with levels of stress, according to Thompson. see: J.R. Thompson, "Making Research Work", <u>Alberta Hog Journal</u>, Vol. 7, No. 1 (Winter 1978), p. 30.

animals which cause not only belly shrink [and excretory shrink] but tissue shrink as well."[1] Figure 3-2 shows how different handling methods might affect stress.

Many different sizes of trucks are used to ship hogs in Alberta, varying from half-ton trucks to liners with a capacity of 220 or more hogs. Conditions on board the trucks vary considerably among handlers. Ideally, trucks should not be overloaded, hogs should have clean, dry straw on the floor, adequate ventilation should be provided, large truckloads should be partitioned, trucks should be covered, and driving should be done as smoothly and carefully as possible. Density of hogs loaded on trucks tends to be variable among producers and shipments, but can have effects on stress and shrink.[2]

## Alternative Feeding Methods

Several possibilities exist for selection of feeding methods in preparation for shipping hogs. Some producers will take hogs off feed well in advance of shipment (i.e. the night before shipment) while others keep hogs on feed until shipping time. Different feed diets have been experimented with (see Chapter II) but none of the previous studies cited found preshipment variations in feed diets to have statistically significant effects upon tissue shrink.

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[1] Clive R. Harston, Shrinkage Depends on Where, When and What You Market, Circular 221 (Bozeman: Montana State College, April 1959).

[2] Thomas T. Stout and Jack H. Armstrong, Shrink and Yield in Market-Fed Hogs, Research Bulletin No. 710 (Lafayette: Purdue University Agricultural Experiment Station, December 1960), p. 3.

Figure 3-2

POTENTIAL EFFECTS OF ALTERNATIVE HANDLING METHODS ON STRESS

| Levels of stress | | |
|---|---|---|
| Low | Moderate | High |
| Pushing hogs with board | Use of slapper | Electric prod |
| Level loading chute | | Steep ramp |
| Wide aisles, fully open endgate | | Narrow aisles, tight corners, narrow endgate openings |
| Hogs not crowded on truck | | Hogs crowded and cramped on truck |
| Cool or moderate weather | | Extremely hot or cold weather |
| Straw-covered, level floor (good footing) | | Slippery, uneven floor |
| Covered loading ramp and truck | | Loading ramp and truck exposed to weather and bright sunlight |
| Smooth, careful driving | | Rough, erratic driving |
| Use of dividers for large loads | | Large truckloads of hogs with no dividing walls |
| Maintenance of a constant environment | | Any extreme environmental change |

Source: Compiled by author from various sources.

Time last fed was found to be an important shrink factor in most previous studies; however, the effects vary considerably given different conditions. For example, Harston suggested that "overfilled" animals often become "uncomfortable" when shipped, leading to "nervousness, excessive pushing, and crowding."[1] Even a normal fill may not provide any advantages for shorter shipments. Stout and Armstrong showed that "there is no advantage in feeding hogs intended for immediate slaughter . . . yields of fed hogs compare unfavorably to those of unfed hogs when the hogs are shipped 100 miles and, presumably, shorter distances or when slaughtered immediately."[2] Yet for longer shipments (well over 100 miles in their test), Stout and Armstrong observed that yields of hogs fed just prior to shipment tend to be higher as distance increased, than for hogs taken off feed for some time before shipment.[2] As such, it becomes difficult to recommend any one feeding program for all producers, because each one of them faces a unique marketing situation.

## The Decision Process

In conclusion, it becomes apparent that producers face a series of decisions when choosing among marketing alternatives. Each decision can result in different levels of costs and benefits to the

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[1] Clive R. Harston, Shrinkage Depends on How You Market, Circular 222 (Bozeman: Montana State College, April 1959), p. 3.

[2] Thomas T. Stout and Jack H. Armstrong, Shrink and Yield in Market-Fed Hogs, Research Bulletin No. 710 (Lafayette: Purdue University Agricultural Experiment Station, December 1960), p. 3.

producer, but no ideal solution can be applied to all producers in general. Different feeding, shipping, and handling programs will interact with one another to produce variable consequences under different constraints. Hopefully the concepts discussed in this study will serve as an aid to producers in the course of their decision making.

CHAPTER IV

# METHODOLOGY
## PHASE 1: DIRECT DELIVERIES

### Scope of the Study

The first part of the study involved hogs delivered directly to Fletcher's meat packing plant at Red Deer.[1] This location was chosen for the following reasons: (1) Hogs shipped to Fletcher's for slaughter are held at the A.H.P.M.B. assembly yard; therefore, tests could be run at a Board supervised location, while at the same time closely simulating actual plant holding-yard conditions. (2) Many of the hogs arriving at the Red Deer terminal are delivered directly to the plant rather than through various assemblers. Direct deliveries were preferred over assembled lots since the prior treatment of the hogs could be more easily traced with the direct deliveries. (3) The total number of hogs produced in the Red Deer area (C.D. 8) is the highest for any census district in Alberta,[2] which meant that a larger, more concentrated population was available from which to draw participants.

The size of the study was partly limited by cost constraints. A payment of $1.50 per hog used in the study was made directly to producers, as compensation for shrink losses incurred in the study.

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[1] This study consists of two major phases which are closely related but which have separate procedures and analyses. The two parts are later brought together in the examination of the results, but in this chapter they are discussed separately as phase 1 and phase 2.

[2] Alberta Agriculture, Agriculture Statistics Yearbook 1977 (Edmonton: Alberta Agriculture, 1978), p. 52.

Time was also a constraint on the size of the study. Management of Fletcher's and the A.H.P.M.B. assembly yard agreed to permit testing of a maximum of 200 hogs per week for up to 10 weeks. The duration of this study was from September 12, 1978 to November 9, 1978, under fall weather conditions.

Twenty-seven different producers participated in the study. Some of the criteria for participation were that direct deliveries could be made to Fletcher's (either by the producer or his trucker, but not in assembled lots), delivery could be made on Tuesdays, and that $1.50 per hog was acceptable as payment to compensate for shrinkage during the test. A total of 57 shipments was received for the test from the 27 producers. The average size of each shipment was 25.6 hogs, although lot sizes ranged from 8 to 65 hogs. No required load size was specified for the sample. The number of deliveries per producer ranged from 1 to 9 loads.

## Variable Selection

As discussed in Chapter II, all variables found to significantly affect shrinkage in previous studies were also examined in this study, with the exception of seasonality.

In some previous studies, breed of hog was found to significantly affect yield, but not shrink. In this study an attempt was made to collect information on breeds. However, some producers did not know what the breeds of their hogs were, some only had a rough idea of what the breeds were, and others did not know the ratios of breed crosses. From the producers who were able to supply precise information on breeds, it was apparent that a very heterogeneous mixture of hog breeds was involved in this sample.

Because precise information on breeds was not available for most of the hogs in this sample, breed was not included as a variable.

Feed restriction was found to be significant for both yield and shrink. While the type of feed restriction during the actual finishing period was not recorded as a variable, the time of last feeding (A.M. or P.M.) was recorded, and used as an estimator for the amount of fill in a load of hogs.

Finish of hogs was shown to have significant effects on both yield and shrink in previous studies. Feed diets and liveweight were also shown to affect finish. Because breed affects carcass configuration, it consequently results in variability of finish between breeds. Since finish affects yield, it is used in this study as a control variable to compensate for its contribution to yield. Carcass grade index was used as an estimate of fatness, or finish.

## Test Procedure and Data Collection

As a participating producer arrived at the Red Deer terminal, his hogs would be checked to determine whether or not they had been tattooed prior to arrival.[1] A load of tattooed hogs would then be divided into three groups of equal (plus or minus one hog) size just before they entered the scale. Each of the three groups was weighed, then moved into one of three holding pens: pen A for immediate slaughter, pen B for a 24 hour delayed slaughter, and pen C for a 48 hour delayed slaughter. As a result, each of pens A, B, and C contained approximately one third

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[1] Each producer's hogs are tattooed with a unique series of alpha-numeric combinations, in order to identify the carcass.

of all the hogs tested each week. If the hogs had not previously been tattooed, each group from each producer was tattooed with a unique identification, to facilitate the collection of carcass data.

Hogs in pen A were slaughtered Tuesdays[1] shortly after noon. Pen B hogs were sent to the plant Wednesdays just after noon, and the pen C hogs were slaughtered Thursdays just after noon. For most of the study, water was available *ad lib* to the hogs with the exception of the final two weeks due to freezing conditions. No feed was given to the test hogs at the Red Deer terminal. The purpose of this procedure was to estimate what effects holding of hogs for 24 and 48 hours would have on yields, compared to immediate slaughter under simulated plant-holding conditions. By splitting a particular producer's load of hogs into the three groups, characteristics of the hogs (i.e. those affected by breed, handling methods, and feeding methods) are held constant among the groups and time becomes the major exogenous variable acting upon yield.

Because every hog was not individually weighed (due to time constraints at the yards) an average carcass yield for each group was calculated.[2] Because each of a producer's three groups were weighed at nearly the same time (within minutes of each other) any differences in yield from one group to another would therefore be attributable to

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[1] Tuesdays were selected for test deliveries with subsequent groups slaughtered on Wednesdays and Thursdays. This was done to avoid weekend hold-overs, backlogs on Mondays, and long weekend holidays.

[2] $$\text{Average group yield} = \frac{\text{Total group carcass weight}}{\text{Total group liveweight}} \times 100$$

either: (a) the differences in average liveweight among the groups[1] and/or (b) the differences in the times held prior to slaughter,[2] and (c) any random error.

As each delivery of hogs arrived at the terminal, producer data were also collected. Appendix C is a copy of the data list collected for each shipment. These data were collected in order to make comparisons among producers by using individual handling, trucking and feeding methods as the criteria for any resultant differences in tissue shrink.

It should be noted that in the first three weeks of the study, the three test groups were not weighed individually as they arrived at the terminal with the exception of the very first load of 13 hogs. (A total of 418 hogs was tested over the first three weeks). Instead, they were weighed as one load, then split randomly into three groups. This meant that only an average liveweight could be assigned to each of the three groups, because they were not re-weighed individually. In some cases, the average of a load might be very close to the true average weight of a group, particularly for larger groups of hogs, or with more uniformly sized hogs. However, as the range of hog weights within a load increases, the likelihood of the estimated group weight being close to the true group weight may have diminished, especially for smaller groups. In the forthcoming analysis, the potential

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[1] Richard D. Gibb, "Hog Shrinkage", Research in Agriculture, Bulletin 40, No. 5 (Macombe: Western Illinois University, October 1961), p. 12.

[2] Knute Bjorka, Shrinkage and Dressing Yields of Hogs, Technical Bulletin No. 621 (Washington, D.C.: U.S. Department of Agriculture, June 1938), p. 3.

discrepancy due to this procedural flaw was duly noted and subsequently those data were rejected.

## Treatment of the Data

Multiple regression analysis was used to test the hypotheses, primarily because this technique is useful "to control for other confounded factors in order to evaluate the contribution of a specific variable or set of variables."[1] By using yield as a dependent variable, effects of the independent variables upon yield were interpreted to be analogous to the effects they have upon tissue shrink. More precisely, if different groups of hogs exhibit different yields from day 1 to day 3, some external factors must be affecting rates of shrink.

The time from weighing hogs upon arrival at the terminal to time of slaughter (hereinafter referred to as *time*) was one of the independent variables used in the regression, to test for effects of *time* on *yield*.

Since it was hypothesized that shrink rates were a non-linear function of time, a regression using the $\text{logarithm}_{10}$ of time was compared to a linear regression, to determine the validity of that hypothesis.

The distance from farm to plant was entered as the *distance* variable.

The carcass index was also used as a variable in the regression to test the relationship between fatness and yield. The average

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[1] Norman H. Nie, et al., Statistical Package for the Social Sciences, 2nd ed. (New York: McGraw-Hill Book Company, 1975), p. 321.

index of all hogs in each group was used as a single variable (*fatness*) to represent that particular group.

In addition to *fatness*, average group liveweight was used as an independent variable, to test the hypothesis that heavier hogs shrink at different rates than lighter hogs. (i.e. To test the relationship between weight and shrink rates). This variable was denoted as *live-weight*.

The *air temperature* variable was the mean kill day temperature for pen A hogs, the average of the mean day 1 and day 2 temperatures for pen B hogs, and the average of the mean day 1, 2, and 3 temperatures for pen C hogs.[1]

The time of the last feeding was represented by a dummy variable since all hogs tested were last fed either the morning of shipment (A.M.) or the evening before shipment (P.M.). This variable was called *time last fed*.

Another dummy variable was used to represent the availability of water to hogs held in the yards. As previously discussed, the watering system was shut off for the final two weeks of the test. The potential effects of this change were tested using a dummy variable termed *water availability* to represent water off or water on. It must be realized that the effects of not watering hogs were confounded with effects of low temperatures, and as such, are inseparable.

Density of a load of hogs on a truck was suggested to have an impact upon levels of stress. This variable, *density of load*, was

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[1] This method of deriving the *air temperature* variable was developed in consultation with Dr. B.A. Young, Department of Animal Science, The University of Alberta.

represented by taking the size of the truck bed ($m^2$) and dividing by the number of hogs on board to determine the number of square meters of space per hog. Once again, this variable was tested as an independent variable acting upon yield.

Finally, hypothesis number 9 (see Chapter I), which suggested that rougher handling methods may affect shrink rates, was tested using dummy variables to represent the level of stress. Stress levels of 0 or 1 (low or high) were established by combining effects of various moving and loading methods (as described in Figure 3-2). Basically, three factors were considered in determining the stress levels. The method of moving hogs (e.g. electric prod, slapper, push board), the type of loading facility (e.g. level chute, inclined ramp) and the location of the loading facility (e.g. indoor or outdoor) were considered. If two or more high stress factors were involved in a particular producer's handling methods, the variable for stress was assigned a one. If two or more medium and/or low stress factors were present, the variable was assigned a zero. The limited number of dummy variable cases created for *handling stress level* was because of the intangible nature of this factor. Stress is present in varying degrees, and to attempt to delineate it into a more detailed ordinal scale would only serve to reduce the degrees of freedom in the regression without adding to the significance of the relationship.

The variables discussed were entered in a stepwise multiple regression in an SPSS (Statistical Package for the Social Sciences) computer program. The purpose of this regression was to determine which variables were significant (and thereby accept the alternate hypotheses)

and then to empirically determine the relationship between *yield* and the significant independent variables.[1] Figure 4-2 shows the functions tested in the regression, and summarizes the variable list.

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[1] "The general form of the (unstandardized) regression is $Y' = A + B_1X_1 + B_2X_2 + \ldots + B_kX_k$ where Y' represents the estimated value for Y, A is the Y intercept and the $B_i$ are regression coefficients. The A and $B_i$ coefficients are selected in such a way that the sum of squared residuals $(Y - Y')^2$ is again minimized . . . The actual calculation of A and $B_i$ requires a set of simultaneous equations derived by differentiating $(Y - Y')^2$ and equating the partial derivatives to zero." : see Norman H. Nie, et al., Statistical Package for the Social Sciences, 2nd ed. (New York: The McGraw-Hill Book Company, 1975), p. 328.

Figure 4-2

REGRESSION FUNCTION AND VARIABLE LIST

*Yield* = f (*time, fatness, liveweight, air temperature, distance, density of load, time last fed, water availability, handling stress level*).

$$\textit{Yield} = \frac{\text{total hot carcass weight of a group}}{\text{total liveweight of a group}} \times 100\ (\%).$$

*Time* = Time from weighing in at yards to time of slaughter (min.)

*Log Time* = $\text{Logarithm}_{10}$ of *time*.

*Fatness* = Average carcass grade index of a group.

*Liveweight* = Average liveweight of a group taken upon arrival at the yards (kg/hog).

*Air Temperature* = Mean kill day temperature for pen A hogs, average of mean day 1 and day 2 temperatures for pen B hogs, and average of mean day 1, 2 and 3 temperatures for pen C hogs.

*Distance* = Distance shipped from farm to A.H.P.M.B. terminal (km).

*Density of Load* = Truck bed area/No. of hogs ($m^2$/hog).

*Time Last Fed* = Dummy variable: 0 = A.M. last fed, 1 = P.M. last fed.

*Handling Stress Levels* = Dummy variable: 0 = low, 1 = high.

*Water Availability* = Dummy variable: 0 = water on, 1 = water off.

# METHODOLOGY
# PHASE 2: ASSEMBLED LOADS

## Scope of the Study

The second phase of the study sampled thirteen liner loads of hogs shipped from Lethbridge and Calgary to Edmonton and Red Deer. Points of origin and points of destination, as well as the number of loads sampled, were selected after discussion and specified terms of agreement with A.H.P.M.B. representatives.

The purpose of this phase was to examine several variables affecting large loads of assembled hogs shipped over varying distances, and relate them to yield figures. The samples included eight shipments from Lethbridge to Edmonton (515 km - two to each of the four major Edmonton meat packing plants: Burns, Swift Canadian, Canada Packers, and Gainers), one shipment to each of the Edmonton plants from Calgary (300 km), and three shipments from Calgary to Fletcher's at Red Deer (140 km). A total of 2694 hogs were sampled in phase 2.

The shipments studied took place between December 4, 1978 and February 7, 1979. Loads were selected at the discretion of the personnel working at the assembly yards, in order to avoid busy shipping periods, since additional time and labor were required for collection of the additional data.

## Test Procedure and Data Collection

Pertinent data were collected by cooperating personnel at the two Board assembly yards, and at the various packing plants involved. As each individual producer's load arrived for assembly, the tattoo

number, distance shipped, the number of hogs, load liveweight, and time of weighing were all recorded.

Once an entire liner load was assembled, the following trucker data were collected: name of shipper, destination (name of plant), the number of hogs unloaded (and the number of dead hogs, if any). A sample of the form used for collection of data in phase 2 is shown in Appendix D. Time of kill, hot carcass weights, backfat measures and indexes were all available from the producer cheques.

## Treatment of the Data

By calculating an average carcass weight for each producer's load of hogs, the average yield was obtained by dividing the total carcass weight by the total liveweight of the load (recorded upon arrival at the terminal). This method provided a yield figure for each producer's hogs within a particular lot. Yields were regressed with time from assembly to slaughter, the distance from farm to plant, the average liveweight of a load of hogs, and the average index measure of a load of hogs. Multiple regression was used to determine the following relationship:

$$Yield = f(time,\ distance,\ liveweight,\ fatness).$$

$$Yield = \frac{\text{carcass weight of a load}}{\text{liveweight of a load}} \times 100\ (\%).$$

*Time* = Time from assembly to slaughter (hours).

*Distance* = Distance from farm to slaughter (km).

*Liveweight* = Average liveweight of a load (kg).

*Fatness* = Average carcass grade index of a load.

In addition, an aggregate yield was compiled for each lot of hogs, which allowed for comparisons to be made among lots shipped to the various plants in the test from the three assembly yard locations.

## Procedural Problems

This section reviews some of the unanticipated problems and delays encountered during the course of this study, since some of these problems led to subsequent changes in the research format.

The project was initially set up to test hogs over the hot summer months of July and August 1978, but labor disputes in two of the major meat packing plants commenced in the week in which the project was to have started. The dispute led to undue pressure on hog marketing facilities (particularly at Red Deer) which precluded any use of these facilities for research until termination of the dispute. Unfortunately, this unforseen delay eliminated the opportunity to collect shrinkage data during the hot weather.

When the study began in early September 1978, the initial flow of hogs was slow due to a backlog effect from the plant closures. By the time a substantial number of shipments began to flow in, the grain harvest season was rapidly approaching. This led to a decline in the volume of hogs being shipped to market and some of the producers previously committing hogs for the study ended up holding back shipments during the test period, due to the harvest season.

# CHAPTER V

# ANALYSIS

This chapter discusses the analytical procedures applied to the data in this study. First, it shows some of the descriptive tests which were run on the data, to determine general characteristics of some of the variables. Then an exposition is provided on how the final model was selected from several alternative solutions. The regression analysis is shown, and then a statistical interpretation of the regression is provided. The discussion is then repeated for the phase 2 data.

## Preliminary Analysis of Yields

Yields, by Load. - Yields were calculated for each individual group of hogs. Appendix E lists all yield figures for every group of hogs in the test. Yield changes between day 1, day 2 and day 3 have also been listed, and are used as estimators of shrink losses. An aggregate mean yield was calculated for each kill day; these figures are shown at the end of the lists in Appendix E. As shown, yields on the second and third days averaged 1.3 and 2.4 percent less than the first day, respectively.

Yields, by Week. - Appendix F breaks down the means of all yields on each kill day into weeks of the program. Day to day differences are averaged and summarized in the final column, Yield Change From Day 1. This table facilitates comparison among weeks, for averages of all producers. The only variable directly affected by changes from week to week was *water availability* during the final two weeks of the study.

Variance of Yields. - To test the homogeneity of the data from week to week, variances of the liveweights were compared, using F-tests of

variance ratios to determine the accuracy of the sampling methods in weeks 1, 2, and 3 (where liveweights were not taken for individual groups, but were averaged over a load of hogs). Table 5-1 shows the variances of the means of the groups of liveweights over the nine week period, for each kill day. There was a general increase in the variance of the liveweights after the first three weeks. At a 0.05 level of significance, several variances proved to be significantly different from one another (between the first three weeks and the remaining data), indicating that the data were not homogeneous.

Table 5-1

VARIANCE OF MEAN GROUP LIVEWEIGHT-BY WEEK OF TEST

| Week | Mean of Group Liveweights (kg) | Variance | Mean of Group Liveweights (kg) | Variance | Mean of Group Liveweights (kg) | Variance |
|---|---|---|---|---|---|---|
| 1 | 101.5 | 147.0 | 100.2 | 81.0 | 100.2 | 81.0 |
| 2 | 96.0 | 59.4 | 96.0 | 59.4[b] | 96.0 | 59.4[d] |
| 3 | 95.3 | 93.0 | 95.3 | 93.0[c] | 95.3 | 93.0[e] |
| 4 | 98.7 | 273.5 | 99.0 | 400.7[b] | 97.7 | 250.3 |
| 5 | 94.6 | 385.3[a] | 94.1 | 394.3[b] | 95.2 | 303.1[d] |
| 6 | 102.3 | 83.6 | 100.6 | 85.9 | 101.6 | 211.8 |
| 7 | 102.7 | 379.1[a] | 103.1 | 535.1[b,c] | 103.9 | 491.1[d,e] |
| 8 | 96.3 | 248.2 | 96.3 | 341.9[b] | 95.8 | 235.5 |
| 9 | 97.6 | 241.2 | 99.8 | 289.5 | 97.7 | 107.8 |

* Up to week 3, group liveweights were derived by averaging load weight over the three groups, except for the first load in week 1.

a, b, c, d, e: Denote significant differences among variances within the first three weeks and variances within the final 6 weeks (F-ratio for 95% probability).

Handling Stress. - Initially a series of dummy variables was used to represent the components of *handling stress levels*. However, the nature of the dummy variables created problems of multicollinearity, which showed up as high values (up to 0.89) for the simple correlation coefficients between these dummy variables.

Because of the intangible nature of these variables, a composite scale was developed, to give an overall indication of the stress levels to which the hogs were subjected during handling. A zero was assigned for low stress, and a value of one was assigned to high stress.

## Selection of the Best Model

To further test the data collected in the first three weeks, two regressions were compared; one used all data, and the other deleted the first three weeks. First, coefficients of determination were compared to test for goodness of fit, then the confidence limits were compared to determine which had the better confidence of predictability.

Coefficients of Determination. - The multiple $R^2$ values of the two regressions were compared. Regression 1 for all variables had a multiple $R^2$ of 0.322, and regression 2 with the first three weeks deleted had a multiple $R^2$ of 0.478. Thus, on the basis of these values, regression 2 proved to have a better fit.

Confidence Limits. - For the 95% significance level selected, the z value was 1.96. Then, as suggested by Orr,[1] the standard error of the estimate

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[1] Dale Orr, Applied Econometrics (Toronto: University of Toronto Institute for Policy Analysis, 1977), p. 43.

was compared to $\overline{Y}$.[1] For regression 1, confidence limits were 82.8 and 76.2 (an interval of 6.6% yield) and for regression 2, limits were 81.7 and 77.2 (an interval of 4.5% yield). Because of its smaller confidence interval, the confidence of prediction proved to be superior for regression 2.

On the basis of the preceding tests, regression 2 proved to have a better fit, with more variables contributing, and had a greater level of confidence of prediction. These results led to a decision to eliminate the first three weeks of data from further use in the analysis.

Linearity of the *Time* Variable. - The regression was then run using the last 6 weeks of data and compared to a regression which substituted the logarithm of time for the *time* variable. Goodness of fit was compared, using F-tests for the *time* variables and the equations. The $R^2$ change for the *log time* (base 10) variable was 0.307 as compared to 0.374 for the *time* variable. The multiple $R^2$ for the regression including *log time* was 0.407 and 0.478 for the regression using *time*.

Thus, the model selected was the regression using *time* with the first three weeks of data omitted. (See Appendixes G and H).

## Interpretation of the Regression Equation

F-tests. - Five variables had significant coefficients of determination in the regression. *Time* (from weighing in at yards to slaughter) showed the highest $R^2$ change. The other variables with significant $R^2$ change

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[1] The formula used was $\overline{Y} \pm z \cdot S_y \cdot \sqrt{\frac{n+1}{n}}$, where $S_y$ was the standard error of the estimate, $\overline{Y}$ the mean of the yield, and n the number of observations; See Robert D. Mason, Statistical Techniques in Business and Economics, 4th ed., (Georgetown: Irwin-Dorsey Limited, 1978), p. 484.

were, in order of their entry into the stepwise regression: *fatness*, *air temperature*, *water availability*, and *handling stress levels*. The next variable (entered on step 6) was *distance*, which showed a significant decrease in the $R^2$ change and sequential F value. At a 95% level of significance, the *distance* variable made a non-significant improvement to the $R^2$ value. $F_{(5,111)}$ tests for the variables entered on step 5 (and for *distance*, entered on step 6) are shown in Table 5-2.

Table 5-2

F-TESTS FOR COEFFICIENTS OF DETERMINATION
IN THE PHASE I REGRESSION

| Variable Name | $R^2$ Change | $F_{(5,111)}$ | Table (95%) $F_{(5,111)}$ |
|---|---|---|---|
| *Time* | 0.374 | 83.34 | 2.31 |
| *Fatness* | 0.045 | 7.32 | 2.31 |
| *Air Temperature* | 0.022 | 7.01 | 2.31 |
| *Water Availability* | 0.018 | 4.44 | 2.31 |
| *Handling Stress Levels* | 0.013 | 2.65 | 2.31 |
| **Distance* | 0.003 | 0.57 | 2.19 |

*Tested on step number 6 - not significant.

t-Tests. - Next, t-tests were applied to determine significance levels of individual parameters. The B coefficients from step 5 were tested using a z distribution as an estimate of the t-values. In addition, the probability of Type I error was determined for the five variables. *Handling stress levels* showed the highest probability of Type I error (0.103) as shown in Table 5-3.

Table 5-3

t-TESTS OF B COEFFICIENTS AND PROBABILITY OF TYPE I ERROR IN THE PHASE I REGRESSION

| Variable Name | B Coefficient | t-Value | Area Under Curve | Prob. of Type I Error |
|---|---|---|---|---|
| *Time* | -0.0489 | 9.1 | 0.999 | 0.001 |
| *Fatness* | -0.1145 | 2.7 | 0.993 | 0.007 |
| *Air Temperature* | -0.1102 | 2.6 | 0.991 | 0.009 |
| *Water Availability* | -0.5310 | 2.1 | 0.964 | 0.035 |
| *Handling Stress Levels* | -0.3871 | 1.6 | 0.897 | 0.103 |
| *Constant* | 93.70 | | | |

Confidence Limits. - Confidence limits for the regression equation were calculated at several levels of significance. These are shown in Table 5-4.

Table 5-4

CONFIDENCE LIMITS OF THE PHASE I REGRESSION AT SELECTED LEVELS OF PROBABILITY

| Significance Level (%) | z Value | Std. Error (Step 5) | $\overline{Y}$ | Upper Limit | Lower Limit | Confidence Interval |
|---|---|---|---|---|---|---|
| 99 | 2.58 | 1.13 | 79.41 | 82.3 | 76.5 | 5.9 |
| 95 | 1.96 | 1.13 | 79.41 | 81.6 | 77.2 | 4.4 |
| 90 | 1.64 | 1.13 | 79.41 | 81.3 | 77.5 | 3.7 |

## Analysis of Assembled Lots - Phase 2

As in phase 1, a multiple regression was used to analyse effects of the exogenous variables upon yield. Tests similar to those

run in phase 1 were applied to phase 2. The list of data used in the phase 2 regression is shown in Appendix I.

None of the variables in the phase 2 regression showed significant coefficients of determination when tested with F-tests. In addition, none of the B-coefficients were significant when tested with t-tests. Possible reasons for non-significance of these variables are discussed in Chapter VI. A summary table of this regression is shown in Appendix J.

# CHAPTER VI

# CONCLUSIONS AND RECOMMENDATIONS

This chapter first evaluates the hypotheses, then quantifies some of the results of the analysis into costs. Some recommendations are also suggested, to aid in the marketing programs of producers and in some potential policy modifications.

## Hypothesis Test Results

Hypothesis 1. - Accept $H_1$. There is a significant relationship between tissue shrink and the time span from arrival at the plant to slaughter. The results of the phase 1 analysis showed *time* to be the most significant variable. The sign of the coefficient was negative, indicating that as time from arrival at plant to time of slaughter increased, yield decreased. This implies that tissue shrinkage increased over the time period studied. For phase 2, the *time* variable was not significant. On this basis, $H_0$ would be accepted. However, there is a possibility that the data in phase 2 were too restrictive for the time variable, and that the results were actually inconclusive rather than non-significant. (While *time* in phase 1 ranged from 1 to 48 hours, the mean of *time* in phase 2 was 25.0 hours with a standard deviation of only 2.2 hours.)

Hypothesis 2. - Accept $H_0$. There is no significant relationship between tissue shrink and transit time (distance shipped). Both phase 1 and phase 2 showed non-significant results for the *distance* variable. While phase 1 was generally comprised of short distance shipments, phase 2 included shipments ranging from 150 to 590 km. The distinction between distance and transit time was not made in this study (distance was an

estimate of transit time), but the confounding of *distance* and time from assembly to slaughter for the variables in phase 2 is discussed later.

Hypothesis 3. - Accept $H_0$. There is no significant change in the rate of shrink over time. The validity of this hypothesis was tested using a logarithmic function (base 10) of *time* to determine if a curvilinear function had a better fit than a linear function of *time*. The $R^2$ value for the $\text{logarithmic}_{10}$ function was lower, indicating that the function approximated linearity (at least up to 48 hours - the effect beyond 48 hours was not determined in this study). This hypothesis was not tested in phase 2 due to the limited range of the *time* variable.

Hypothesis 4. - Accept $H_0$. The rate of shrink is not significantly different for lighter than for relatively heavier hogs. The liveweight variable was not significant in phase 1 or phase 2.

Hypothesis 5. - Inconclusive results. The study was unable to show significance in the relationship between rates of shrink and the relative fatness of hogs. The *fatness* variable was significant in phase 1, but not significant in phase 2. However, the carcass yield of a hog *per se* is affected by fatness as discussed in Chapter II. Because of this effect, it becomes difficult to distinguish between effects of fatness on yield as opposed to shrink, and the primary reason for inclusion of this variable was to remove the effects of fatness on initial yield from the regression.

Hypothesis 6. - Accept $H_1$. Rates of tissue shrink are significantly related to air temperatures. This variable was only tested in phase 1, and was significant in the regression. However, an unforeseen circumstance led to confounding of this variable with the effects of *water availability*. Because the occurrence of low temperatures was

coincidental with the closure of the watering facilities, the effects of these variables should not be considered separately. However, the effects of the variables on yields were in opposite directions. The *air temperature* coefficient had a negative sign, indicating that as temperatures increased, yields decreased. *Water availability* also had a negative coefficient, meaning that with a dummy variable of 1 (no water available), yields decreased. The implications of these results would indicate that both temperature and watering will have significant effects on shrinkage, but that the effects as described in this study should not be separated for purposes of quantification.

Hypothesis 7. - Insufficient evidence. ($H_0$ was: rates of tissue shrink are not significantly different for hogs fed just prior to shipment than for hogs which have been confined from feed for some time period prior to shipment.) The *time last fed* variable was not used in phase 2, and in phase 1, five loads had hogs taken off feed the evening prior to shipment. Had the variable been significant, it would have been difficult to separate effects of *time last fed* (used as an estimator of fill) on yield as opposed to shrinkage, because it is a factor previously shown to affect both yield and shrinkage. Its inclusion was therefore to account for its effects on intial yield in the regression.

Hypothesis 8. - Accept $H_0$. There is no significant relationship between rates of shrink for densely loaded hogs on a truck and less densely loaded hogs on a truck. This variable was tested in phase 1, using the area of the truck bed divided by the number of hogs on the truck ($m^2$/hog). The *density* variable was not significant for this experiment. Its effects were not tested for the long-term situations (long distance shipments) in phase 2, although most liners run filled to capacity with

hogs, which would make the load density constant among the large shipments.

Hypothesis 9. - Accept $H_1$. There is a significant relationship between rates of shrink and levels of handling stress. The phase 1 results showed that levels of handling stress did significantly affect shrink. The coefficient of the B variable was negative indicating that as stress increased (i.e. a value of 1), yields tended to decrease. The specific factors considered in designing the *handling stress level* variable were the methods of loading hogs (i.e. electric prod, slapper) and the type of loading facility the hogs were subjected to.

## Cost Evaluation of Shrinkage Factors

Five of the variables discussed in this study were shown to have significant effects on shrinkage or yield: *time* (from arrival at the plant to time of slaughter), *fatness, air temperature, water availability,* and *handling stress levels*. Because the effects of *fatness* on initial yield versus shrinkage rates were inseparable, and the effects of *air temperature* and *water availability* were confounded, these variables will not be discussed in the cost evaluation, but will be discussed in the recommendations. Because the handling stress variable was a composite of various handling factors which were not separated in the calculations, these are not considered in the cost evaluation.

Time Effects on Cost. - The B coefficient for *time* was calculated to be 0.049 %/hour after conversion to hours. To determine the percentage yield loss, the coefficient is multiplied by the time span under consideration (in hours). For example, a 24 hour delay would result in 0.049 %/hour x 24 hours = 1.18 % yield weight loss. To convert yield

weight loss to carcass weight loss, the coefficient was multiplied by 100 % divided by the average yield in the test (79.4 %) or 1.26, giving a new coefficient of 0.061 % carcass weight loss per hour.

The product of the percent carcass weight loss and the carcass weight will give an estimate of the carcass weight loss. For example, using an 80 kg carcass held for 24 hours:

$$.061\ \%/\text{hour} \times 24\ \text{hours} \times (80\ \text{kg}/100\ \%) = 1.17\ \text{kg}.$$

To derive the cost, the product of carcass weight loss and price is calculated. Thus, the *cost of time* estimating equation is

$$.061 \times \text{time held} \times \text{carcass weight}/100 \times \text{price per kg} = \text{cost/carcass}.$$

This equation is an estimate of cost, but only under average conditions as specified in the test. However, the confidence interval for the time coefficient was calculated to be ± 0.011 %/hour at the 95% level of confidence, and ±0.015 %/hour at a 99% level of confidence.

## Aggregate Effects of Shrinkage

Shrinkage costs become even more significant when put into a larger perspective than an individual hog basis. For example, look at a producer marketing 1000 hogs a year. If his hogs average 80 kg carcass weight, the price averages \$1.75/kg, and the average delay on a load is 10 hours (which might have been avoided), the producer could be losing: 0.061 %/hour x 10 hours x 80 kg/100 % x \$1.75/kg x 1000 hogs = \$850 per year on shrinkage alone.

Or, if all hogs in the province average a delay of 12 hours, under conditions as defined in the test, for 80 kg hogs at \$1.75/kg,

and using the 1977 provincial hog slaughter[1], the total loss to the industry would be:

0.061 %/hour x 12 hours x 80 kg/100 % x \$1.75/kg x 1172488 hogs = \$1201566 or approximately 1.2 million dollars.

## Liveweight Shrink Losses

In addition to tissue shrink and yield analysis, some general data were collected for purposes of estimating liveweight losses. All pen B and pen C hogs were reweighed (each as a pen) prior to slaughter so that an average weight loss per pen could be determined. First, the initial liveweights of all hogs were averaged out for each week (and for each group during the final six weeks). The pre-kill liveweight of each pen was then averaged over the number of test hogs weighed that day. Table 5-5 shows the total liveweight loss per hog by week and kill day. The percentage loss is the average weight loss per hog as a percentage of the initial liveweight.

On the average, Day 2 hogs lost 4.8 kg (5%) while Day 3 hogs averaged an additional 2.2 kg loss (2.5%) for a total loss of 7.2 kg (-7.5%). It appears that live shrink occured at almost double the rate during the first 24 hours than during the following 24 hours. This suggests that a much higher proportion of shrinkage during the early stages might have been excretory shrink assuming that the effects of time on tissue shrink were linear as indicated by the lower $R^2$ for *log time* versus *time* in the two regressions. For example, Appendix E

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1 Alberta Agriculture, Agricultural Statistics Yearbook 1977 (Edmonton: Alberta Agriculture, 1978), p. 55.

showed that the mean change in carcass yield of first day hogs was -1.3%, and for second day hogs was an additional -1.1%. Since the percentage liveweight loss and the percentage yield loss were both based upon initial liveweight, they can be proportionately compared with one another. Of the 5% liveweight loss during the first 24 hours, 1.3/5, or 26% of the loss was carcass yield loss. During the second 24 hour period, although the average carcass yield loss was only 0.2% less than the first, the yield loss as a proportion of the total loss was higher, at 1.1/2.5, or 46%.

It might therefore be concluded that total shrinkage increases at a decreasing rate over time. Most of the decrease in rates can be attributed to excretory shrinkage because tissue shrinkage rates remained fairly constant over the two time periods.

Table 6-5

AVERAGE LIVEWEIGHT SHRINK OF EACH PEN OVER 24 AND 48 HOURS

| | Pen B (24 hours) | | | Pen C (48 hours) | | | |
|---|---|---|---|---|---|---|---|
| Week | Average Initial Livewt. (kg) | Average Weight Loss (kg) | Percent Weight Loss (%) | Average Initial Livewt. (kg) | Average Weight Loss (kg) | Percent Weight Loss (%) | Change From Day 2 (%) |
| 1 | 97.0 | 2.7 | 2.8 | 97.0 | 8.2 | 8.4 | 5.6 |
| 2 | 96.2 | 4.5 | 4.7 | 96.2 | 7.7 | 8.0 | 3.3 |
| 3 | 94.3 | 5.4 | 5.7 | 94.3 | 6.4 | 6.8 | 0.9 |
| 4 | 97.1 | 5.4 | 5.6 | 95.7 | 7.7 | 8.0 | 2.4 |
| 5 | 94.3 | 4.5 | 4.8 | 96.2 | 6.4 | 6.6 | 1.8 |
| 6 | 100.2 | 5.4 | 5.4 | 101.2 | 6.8 | 6.7 | 1.3 |
| 7 | 103.0 | 5.9 | 5.7 | 103.4 | 7.3 | 7.0 | 1.8 |
| 8 | 93.9 | 5.0 | 5.3 | 93.9 | 7.7 | 8.2 | 2.9 |
| 9 | 98.4 | 4.5 | 4.6 | 97.5 | 6.8 | 7.0 | 2.4 |
| MEAN: | | 4.8 | 5.0 | | 7.2 | 7.5 | 2.5 |

## Other Conclusions

When comparing results of phase 1 with phase 2, the *time* variable proved to be highly significant for the phase 1 study but was not significant for phase 2. As discussed in the hypothesis, while the distances shipped in phase 2 ranged from 120 to almost 600 km, the times from assembly to slaughter in phase 2 had a very limited range. Combining the results, it may be suggested that time from farm to slaughter is the most important factor in shrinkage, rather than distance, although distance is related to time in transit, and may have some marginal contributory effects which did not show in this study.

## Recommendations to Producers

To avoid using the specific conclusions drawn from the assumptions in this study as a basis for decision making, the recommendations of this study are made for the general case rather than for specific situations. If a producer does happen to face a marketing situation similar to one described by the conditions surrounding the tests made in this study, the given cost equations could provide a more accurate assessment of the costs, as compared to a producer whose marketing program differs from those tested here.

Minimize Time. - A 24 hour time span between the farm gate and slaughter can result in losses in the range of 1 to 2 kilograms of carcass weight per hog, even under ideal marketing conditions. Furthermore, shrink losses progressed at a continuous rate for at least the following 24 hours and did not appear to decline which had been previously hypothesized. Under adverse conditions, costs of tissue shrink can become even

greater, and these costs are usually proportionately related to the time factor. Thus, the most critical factor is time, and in order to provide the lowest possible shrink costs, marketing time must be minimized.

Minimize Stress. - Minimization of stress in the handling of hogs can be useful in deterring shrink rates. By placing additional stress on hogs through rough or careless handling methods, shrink rates were increased in this study.

Air Temperature and Watering Hogs. - Cooler temperatures appeared to decrease shrink rates, while shutting off water supplies in the yards appeared to increase shrink rates. Producers should attempt to market hogs during cooler weather, whenever a choice is available. Producers should also attempt to ensure that their hogs receive drinking water while they are held over at any point during marketing. Having water available to the test hogs inhibited rates of shrink, and since this should be a relatively low cost means of deterring shrink, producers should be certain that watering facilities are in use.

## Policy Recommendations

Once again, a general overview of the results points out that wherever possible, the marketing system must function to minimize holdovers and delays in shipments of hogs. This objective has been constantly pursued by the A.H.P.M.B., and during the period of their existence, many improvements in the marketing system have been made toward this objective.

Monitoring of time from assembly (or time in at the plant) until slaughter has at times proven to be difficult, and this study was no exception. To ensure an accurate assessment of the holdover time,

the grader's scales (which automatically register weights onto the kill tickets) should be equipped with automatic time clocks to register the time of kill, in order that all parties involved would be aware of any delays in the system. Such a system would permit a reassessment of the current shrink penalty system, by incorporating a system in which shrink penalties gradually increase after a certain minimum standard of time held is exceeded.

Hog marketing policy should ensure that water is always available to hogs, both at assembly yards and at plant holding facilities. If facilities to water hogs are available, they should be inspected frequently to see that they are functioning properly.

Finally, it is important that all sectors of the pork industry realize that the industry has the potential to make substantial savings by taking a positive attitude toward efficiency in marketing. There are certainly costs involved in taking steps to alleviate the shrinkage problem, but when costs of shrinkage reach a million dollars or more in a year, there is likely to be considerable potential for improvement.

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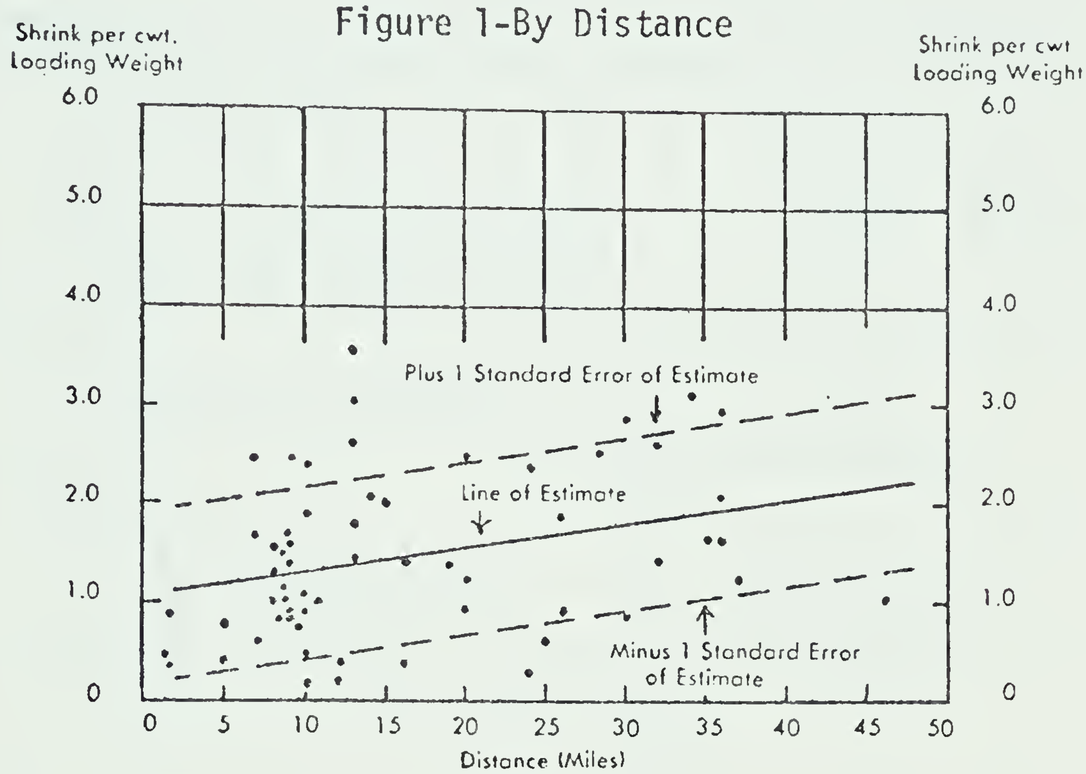
# Appendix A

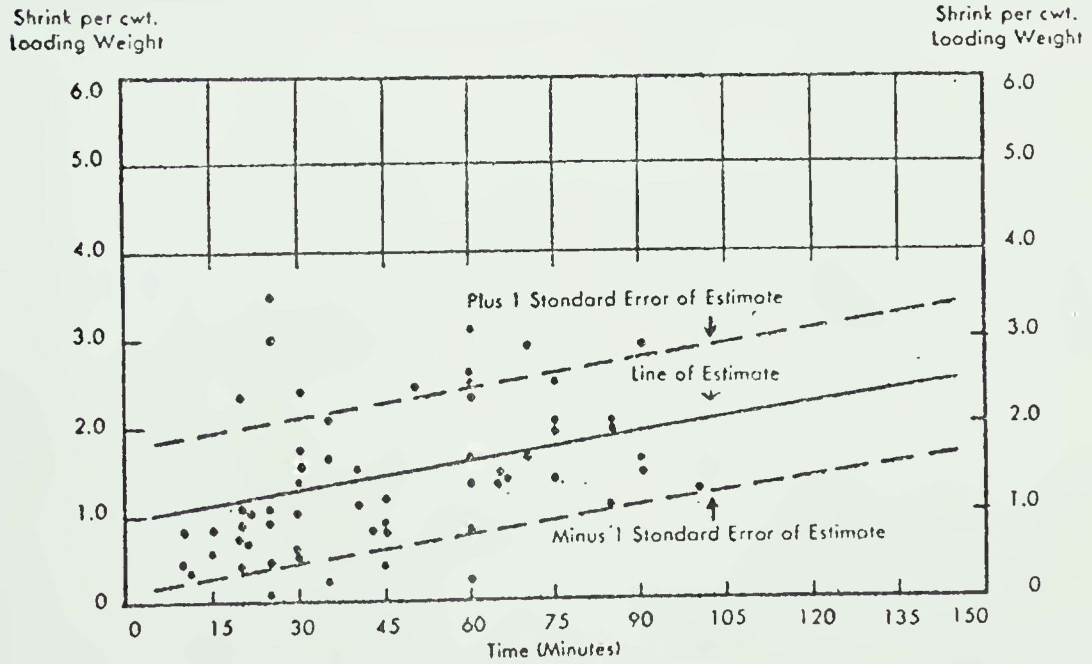
## TRANSIT SHRINKAGE ON 62 LOTS OF MARKET HOGS FROM FARM TO FIRST MARKET, OHIO, JULY 15, 1958 TO DECEMBER 1, 1960

### Figure 1-By Distance




Value for a, 1.05193, b, .02365

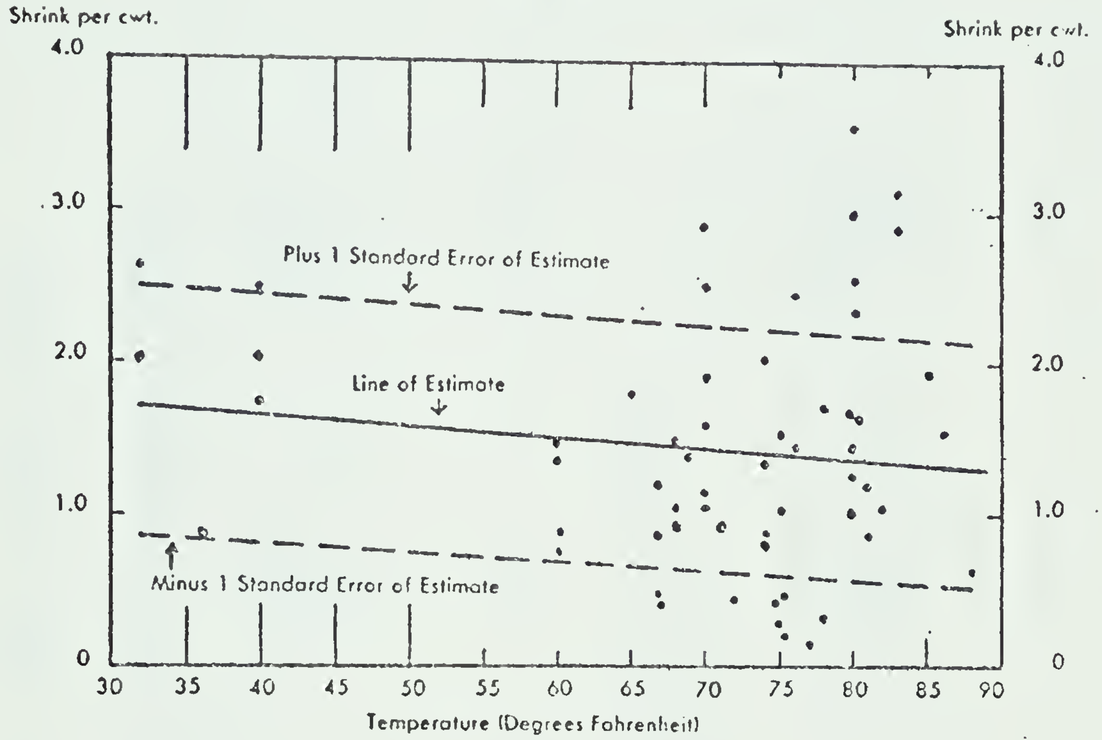
### Figure 2-By Time




Value for a, .91919, b, .00625

Appendix A (Continued)

Figure 3-By Temperature




Source: G.F. Henning and P.R. Thomas, <u>Some of the Factors Influencing Shrinkage of Livestock From Farm to the First Market</u>, Research Bulletin 925 (Wooster: Ohio Agricultural Experiment Station, October 1962).

# Appendix B

RESULTS OF A SHRINKAGE STUDY BY R.D. GIBB (ILLINOIS, 1961).

Table 1: EFFECT OF SUGAR UPON LIVE SHRINKAGE AND TISSUE SHRINKAGE OF HOGS TRANSPORTED A DISTANCE OF APPROXIMATELY 280 MILES (10 SEPARATE SHIPMENTS)

| GROUP | NO. OF HOGS | AVERAGE BEGINNING WEIGHT (LBS.) | AVERAGE WT. AT MARKET (LBS.) | AVERAGE LIVE SHRINK (LBS.) | AVERAGE CARCASS WEIGHTS (LBS.) | AVERAGE DRESSING % |
|---|---|---|---|---|---|---|
| Sugar | 643 | 223.04 | 217.58 | 5.46 | 169.88 | 76.17 |
| Control | 625 | 223.34 | 217.31 | 6.03 | 169.64 | 75.96 |

Table 2: EFFECT OF SPECIAL RATION UPON LIVE SHRINKAGE AND TISSUE SHRINKAGE OF HOGS

| GROUP | NO. OF HOGS | AVERAGE WT. WHEN SORTED (LBS.) | AVERAGE WT. WHEN LOADED (LBS.) | AVERAGE LIVE WT. AT MARKET (LBS.) | LBS. LIVE SHRINK (LBS.) | AVERAGE CARCASS WT. (LBS.) |
|---|---|---|---|---|---|---|
| Special Ration | 135 | 220.48 | 220.96 | 218.85 | 2.11 | 155.54 |
| Control | 137 | 220.83 | 221.56 | 219.45 | 2.11 | 155.93 |

Appendix B (Cont'd.)

Table 3: EFFECT OF DISTANCE UPON LIVE SHRINKAGE OF HOGS

| DISTANCE SHIPPED (MILES) | NO. OF HOGS | AVERAGE BEGINNING WEIGHT (LBS.) | AVERAGE MARKET WEIGHT (LBS.) | AVERAGE LBS. SHRINK (LBS.) | AVERAGE PERCENT SHRINK |
|---|---|---|---|---|---|
| 20 | 340 | 227.50 | 225.14 | 2.35 | 1.03 |
| 50 | 288 | 228.09 | 225.15 | 2.97 | 1.30 |
| 280 | 404 | 230.36 | 223.61 | 6.75 | 2.93 |

Table 4: EFFECT OF TEMPERATURE UPON LIVE SHRINK AND TISSUE SHRINK OF HOGS

| AVERAGE TEMP. | NO. OF HOGS | AVERAGE BEGINNING WEIGHT (LBS.) | AVERAGE MARKET WEIGHT (LBS.) | AVERAGE CARCASS WEIGHT (LBS.) | AVERAGE LIVE SHRINK* (LBS.) | AVERAGE DRESSING PERCENT |
|---|---|---|---|---|---|---|
| $25^{O}F$ | 390 | 223.27 | 219.35 | 167.00 | 3.92 | 74.80 |
| $55^{O}F$ | 373 | 226.93 | 222.09 | 169.77 | 4.84 | 74.81 |
| $86^{O}F$ | 413 | 232.19 | 226.73 | 172.21 | 5.46 | 74.17 |

*Difference is significant at 5% level.

Appendix B (Cont'd.)

Table 5: EFFECT OF TRUCK SPEED UPON LIVE SHRINK OF HOGS (10 OBSERVATIONS)

| NO. OF HOGS | AVERAGE SPEED* (M.P.H.) | AVERAGE TRANSIT TIME (MIN.) | AVERAGE BEGINNING WEIGHT (LBS.) | AVERAGE MARKET WEIGHT (LBS.) | AVERAGE SHRINK (LBS.) |
|---|---|---|---|---|---|
| 149 | 50 | 90 | 226.50 | 223.25 | 3.25 |
| 139 | 40-45 | 100 | 229.79 | 227.12 | 2.67 |

Table 6: EFFECT OF WEIGHT UPON LIVE SHRINK AND TISSUE SHRINK OF HOGS

| NO. OF HOGS | AVERAGE BEGINNING WEIGHTS (LBS.) | AVERAGE MARKET WEIGHT (LBS.) | AVERAGE SHRINK (LBS.) | AVERAGE CARCASS WEIGHT (LBS.) | AVERAGE DRESSING PERCENTAGE |
|---|---|---|---|---|---|
| 302 | 219.92 | 213.77 | 6.15 | 166.27 | 75.61 |
| 325 | 235.04 | 230.85 | 4.20 | 176.25 | 74.98 |

Source: Richard D. Gibb, "Hog Shrinkage", Research in Agriculture, Bulletin 40, No. 5 (Macombe: Western Illinois University, October 1961).

# Appendix C

## SAMPLE QUESTIONNAIRE FOR COLLECTION OF PRODUCER DATA IN PHASE 1

1. Producer name________________________________

2. Producer address________________________________

3. Date of shipment________________________________

4. Loading facility - Ramp________________Level________________
   Enclosed________________Open________________

5. Method of loading - Electric prod____Slapper____Push Board_____

6. Distance in transit________________________________

7. Size of truck box________________________________

8. No. of hogs this load________________________________

9. Tattoo numbers----------GROUP A______GROUP B______GROUP C______

10. Liveweight in at yards--GROUP A______GROUP B______GROUP C______

11. No. of hogs per group---GROUP A______GROUP B______GROUP C______

12. Time of weighing________________________________

# Appendix D

## SAMPLE DATA SHEET-PHASE 2
## (SHIPPER AND ASSEMBLER DATA)

### I. SHIPPER DATA

1. Date______________________________
2. Trucker______________________________
3. Lot number______________________________
4. Terminal location______________________________
5. Time out______________________________
6. Destination (plant name)______________________________
7. Time in at plant______________________________
8. No. of hogs unloaded______________________________

### II. ASSEMBLER DATA

1. Date______________________________
2. Producer______________________________
3. Distance shipped______________________________
4. Number of hogs______________________________
5. Tattoo______________________________
6. Time weighed______________________________
7. Weight of load______________________________
8. Lot number______________________________

## Appendix E

### DAILY COMPARISON OF CARCASS YIELDS, BY LOAD (PHASE 1)

| Date | No. of Hogs | Pen A | | Pen B | | | Pen C | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Arrival Livewt. (kg) | Yield (%) | Arrival Livewt. (kg) | Yield (%) | Yield Change From Day 1 | Arrival Livewt. (kg) | Yield (%) | Yield Change From Day 1 |
| 1978-09-12 | 12 | 107 | 78.6 | 104 | 82.1 | +3.5 | 104 | 82.1 | +1.8 |
| 1978-09-12 | 27 | 100 | 80.9 | 100 | 72.5 | -8.4 | 100 | 73.8 | -7.1 |
| 1978-09-12 | 35 | 96 | 80.6 | 96 | 77.4 | -3.2 | 96 | 81.3 | +0.7 |
| 1978-09-19 | 27 | 102 | 81.2 | 102 | 78.0 | -3.2 | 102 | 77.0 | -4.2 |
| 1978-09-19 | 16 | 97 | 79.8 | 97 | 79.6 | -0.2 | 97 | 78.2 | -1.6 |
| 1978-09-19 | 43 | 92 | 77.5 | 92 | 81.0 | +3.5 | 92 | 76.8 | -0.7 |
| 1978-09-19 | 15 | 99 | 79.9 | 99 | 74.8 | -5.1 | 99 | 76.1 | -3.8 |
| 1978-09-19 | 12 | 96 | 80.0 | 96 | 81.7 | +1.7 | 96 | 84.0 | +4.0 |
| 1978-09-19 | 15 | 96 | 81.0 | 96 | 79.4 | -1.6 | 96 | 77.4 | -3.6 |
| 1978-09-19 | 12 | 94 | 82.0 | 94 | 78.7 | -3.3 | 94 | 78.6 | -3.4 |
| 1978-09-19 | 12 | 92 | 79.7 | 92 | 77.4 | -2.3 | 92 | 76.1 | -3.6 |
| 1978-09-26 | 27 | 94 | 83.8 | 94 | 80.0 | -3.8 | 94 | 81.0 | -2.8 |
| 1978-09-26 | 13 | 97 | 86.5 | 97 | 85.6 | -0.9 | 97 | 84.5 | -2.0 |
| 1978-09-26 | 43 | 87 | 84.1 | 87 | 78.7 | -5.4 | 87 | 77.5 | -6.6 |
| 1978-09-26 | 15 | 93 | 79.9 | 93 | 81.4 | +1.5 | 93 | 76.8 | -3.1 |
| 1978-09-26 | 48 | 97 | 82.2 | 97 | 79.5 | -2.7 | 97 | 77.8 | -4.4 |
| 1978-09-26 | 16 | 99 | 81.3 | 99 | 78.9 | -2.4 | 99 | 77.8 | -3.5 |

Appendix E (cont'd)

| Date | No. of Hogs | Pen A | | Pen B | | | PenC | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Arrival Livewt. (kg) | Yield (%) | Arrival Livewt. (kg) | Yield (%) | Yield Change From Day 1 | Arrival Livewt. (kg) | Yield (%) | Yield Change From Day 1 |
| 1978-09-26 | 30 | 99 | 80.3 | 99 | 79.8 | -0.5 | 99 | 80.4 | +0.1 |
| 1978-10-03 | 33 | 93 | 80.0 | 93 | 79.2 | -0.8 | 93 | 78.6 | -1.4 |
| 1978-10-03 | 26 | 97 | 79.3 | 98 | 80.1 | +0.8 | 101 | 75.7 | -3.6 |
| 1978-10-03 | 36 | 98 | 80.5 | 98 | 78.7 | -1.8 | 97 | 77.6 | -2.9 |
| 1978-10-03 | 45 | 90 | 81.8 | 86 | 81.3 | -0.5 | 86 | 78.5 | -3.3 |
| 1978-10-03 | 28 | 108 | 80.9 | 110 | 81.3 | +0.4 | 103 | 78.8 | -2.1 |
| 1978-10-03 | 14 | 107 | 79.8 | 108 | 80.0 | +0.2 | 106 | 75.8 | -4.0 |
| 1978-10-10 | 15 | 99 | 80.3 | 94 | 78.7 | -1.6 | 97 | 78.0 | -2.3 |
| 1978-10-10 | 31 | 101 | 80.0 | 97 | 79.7 | -0.3 | 99 | 79.0 | -1.0 |
| 1978-10-10 | 37 | 88 | 80.0 | 90 | 79.3 | -0.7 | 90 | 79.3 | -0.7 |
| 1978-10-10 | 13 | 101 | 80.3 | 106 | 79.0 | -1.3 | 100 | 77.9 | -2.4 |
| 1978-10-10 | 31 | 101 | 80.5 | 101 | 80.4 | -0.1 | 103 | 78.3 | -2.2 |
| 1978-10-10 | 12 | 78 | 79.0 | 78 | 80.1 | +1.1 | 80 | 78.4 | -0.6 |
| 1978-10-10 | 39 | 94 | 79.5 | 94 | 79.5 | 0.0 | 98 | 78.5 | -1.0 |
| 1978-10-17 | 25 | 100 | 79.2 | 98 | 77.4 | -1.8 | 99 | 78.4 | -0.8 |
| 1978-10-17 | 64 | 99 | 81.7 | 100 | 79.9 | -1.8 | 100 | 80.0 | -1.7 |
| 1978-10-17 | 13 | 108 | 79.8 | 108 | 77.7 | -2.1 | 104 | 77.2 | -2.6 |
| 1978-10-17 | 18 | 102 | 82.5 | 99 | 80.1 | -2.4 | 103 | 79.9 | -2.6 |
| 1978-10-17 | 28 | 109 | 80.7 | 103 | 79.7 | -1.0 | 114 | 77.3 | -3.4 |
| 1978-10-17 | 15 | 98 | 79.0 | 96 | 79.1 | +0.1 | 93 | 75.2 | -3.8 |
| 1978-10-17 | 36 | 101 | 81.2 | 100 | 79.1 | -2.1 | 97 | 78.7 | -2.5 |

Appendix E (cont'd)

| Date | No. of Hogs | Pen A Arrival Livewt. (kg) | Pen A Yield (%) | Pen B Arrival Livewt. (kg) | Pen B Yield (%) | Pen B Yield Change From Day 1 | Pen C Arrival Livewt. (kg) | Pen C Yield (%) | Pen C Yield Change From Day 1 |
|---|---|---|---|---|---|---|---|---|---|
| 1978-10-24 | 13 | 105 | 80.0 | 104 | 80.2 | +0.2 | 107 | 78.0 | -2.0 |
| 1978-10-24 | 19 | 94 | 79.4 | 92 | 77.9 | -1.5 | 92 | 79.7 | +0.3 |
| 1978-10-24 | 23 | 106 | 81.5 | 104 | 80.2 | -1.3 | 104 | 78.5 | -3.0 |
| 1978-10-24 | 30 | 93 | 80.6 | 95 | 79.5 | -1.1 | 94 | 78.0 | -2.6 |
| 1978-10-24 | 26 | 122 | 83.7 | 127 | 80.2 | -3.5 | 124 | 80.4 | -3.3 |
| 1978-10-24 | 26 | 102 | 82.1 | 104 | 80.8 | -1.3 | 108 | 80.1 | -2.0 |
| 1978-10-24 | 34 | 100 | 79.6 | 101 | 78.2 | -1.4 | 102 | 78.3 | -1.3 |
| 1978-10-24 | 44 | 99 | 82.4 | 98 | 79.4 | -3.0 | 99 | 79.5 | -2.9 |
| 1978-10-31 | 45 | 86 | 83.3 | 89 | 80.1 | -3.2 | 88 | 79.1 | -4.2 |
| 1978-10-31 | 32 | 99 | 80.3 | 101 | 79.6 | -0.7 | 102 | 77.3 | -3.0 |
| 1978-10-31 | 20 | 94 | 79.8 | 93 | 78.6 | -1.2 | 95 | 76.2 | -3.6 |
| 1978-10-31 | 13 | 108 | 77.5 | 109 | 78.7 | +1.2 | 105 | 76.5 | -1.0 |
| 1978-10-31 | 40 | 93 | 78.9 | 87 | 78.3 | -0.6 | 88 | 76.6 | -2.3 |
| 1978-10-31 | 26 | 98 | 79.4 | 99 | 79.6 | +0.2 | 98 | 77.4 | -2.0 |
| 1978-11-07 | 21 | 105 | 80.8 | 105 | 79.1 | -1.7 | 98 | 80.0 | -0.8 |
| 1978-11-07 | 34 | 88 | 80.2 | 93 | 80.6 | +0.4 | 94 | 78.2 | -2.0 |
| 1978-11-07 | 14 | 104 | 80.4 | 111 | 78.3 | -2.1 | 106 | 78.3 | -2.1 |
| 1978-11-07 | 8 | 95 | 82.9 | 94 | 80.4 | -2.5 | 94 | 77.9 | -5.0 |
| 1978-11-07 | 15 | 97 | 81.8 | 97 | 80.9 | -0.9 | 96 | 80.1 | -1.7 |
| Mean: | | 98.2 | 80.7 | 98.2 | 79.4 | -1.3 | 98.2 | 78.3 | -2.4 |
| Std. Error: | | ±0.91 | ±.002 | ±0.99 | ±.002 | | ±0.92 | ±.002 | |

Appendix F

WEEKLY AVERAGE YIELDS, BY KILL DAY

| Week No. | Kill Date | No. of Loads | Mean Carcass Wt. (kg) | Mean Livewt. (kg) | Mean Yield (%) | Yield Change From Day 1 |
|---|---|---|---|---|---|---|
| 1 | 1978-09-12 | 3 | 80.9 | 101.0 | 80.0 | |
| | 1978-09-13 | 3 | 77.6 | 100.2 | 77.3 | -2.7 |
| | 1978-09-14 | 3 | 78.7 | 100.2 | 78.5 | -1.5 |
| 2 | 1978-09-19 | 8 | 76.9 | 96.0 | 80.1 | |
| | 1978-09-20 | 8 | 75.7 | 96.0 | 78.8 | -1.3 |
| | 1978-09-21 | 8 | 75.2 | 96.0 | 78.0 | -2.1 |
| 3 | 1978-09-26 | 7 | 78.7 | 95.3 | 82.6 | |
| | 1978-09-27 | 7 | 76.7 | 95.3 | 80.6 | -2.0 |
| | 1978-09-28 | 7 | 75.6 | 95.3 | 79.4 | -3.2 |
| 4 | 1978-10-03 | 6 | 79.3 | 98.7 | 80.4 | |
| | 1978-10-04 | 6 | 79.3 | 99.0 | 80.1 | -0.3 |
| | 1978-10-05 | 6 | 75.7 | 97.7 | 77.5 | -2.9 |
| 5 | 1978-10-10 | 7 | 75.7 | 94.6 | 79.9 | |
| | 1978-10-11 | 7 | 74.8 | 94.1 | 79.5 | -0.4 |
| | 1978-10-12 | 7 | 74.6 | 95.2 | 78.4 | -1.5 |
| 6 | 1978-10-17 | 7 | 82.4 | 102.3 | 80.6 | |
| | 1978-10-18 | 7 | 79.4 | 100.6 | 79.0 | -1.6 |
| | 1978-10-19 | 7 | 79.3 | 101.6 | 78.1 | -2.5 |
| 7 | 1978-10-24 | 8 | 83.4 | 102.7 | 81.2 | |
| | 1978-10-25 | 8 | 82.0 | 103.1 | 79.6 | -1.6 |
| | 1978-10-26 | 8 | 82.1 | 103.9 | 79.1 | -2.1 |
| 8 | 1978-10-31 | 6 | 76.7 | 96.3 | 79.9 | |
| | 1978-11-01 | 6 | 76.2 | 96.3 | 79.2 | -0.7 |
| | 1978-11-02 | 6 | 74.0 | 95.8 | 77.2 | -2.7 |
| 9 | 1978-11-07 | 5 | 79.2 | 97.6 | 81.2 | |
| | 1978-11-08 | 5 | 79.6 | 99.8 | 79.8 | -1.4 |
| | 1978-11-09 | 5 | 77.1 | 97.7 | 78.9 | -2.3 |

# Appendix G

## LIST OF DATA USED IN THE PHASE 1 REGRESSION

A = Date of kill

B = Number of hogs in group

C = Average carcass weight of a group (kg)

$X_1$ = Time from arrival to time of slaughter

$X_2$ = Distance from farm to yard (km)

$X_3$ = Time last fed (dummy variable)

$X_4$ = Air temperature ($^oC$)

$X_5$ = Water availability (dummy variable)

$X_6$ = Density of load ($m^2$/hog)

$X_7$ = Fatness (index of group)

$X_9$ = Liveweight (average of each group, kg)

Y = Yield (average group carcass weight/average group liveweight)x100

| A | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | B | $X_7$ | $X_8$ | C | $X_9$ | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 912 | 87 | 43 | 0 | 6 | 0 | 0.3 | 4 | 102 | 1 | 84.1 | 107 | 78.6 |
| 913 | 1527 | 43 | 0 | 7 | 0 | 0.3 | 4 | 105 | 1 | 85.6 | 104 | 82.1 |
| 914 | 2967 | 43 | 0 | 8 | 0 | 0.3 | 4 | 102 | 1 | 83.9 | 104 | 80.4 |
| 912 | 117 | 146 | 0 | 6 | 0 | 0.3 | 9 | 108 | 0 | 81.1 | 100 | 80.9 |
| 913 | 1557 | 146 | 0 | 7 | 0 | 0.3 | 9 | 103 | 0 | 72.6 | 100 | 72.4 |
| 914 | 2997 | 146 | 0 | 8 | 0 | 0.3 | 9 | 106 | 0 | 74.0 | 100 | 73.8 |
| 912 | 220 | 38 | 1 | 6 | 0 | 0.4 | 12 | 105 | 1 | 77.5 | 96 | 80.6 |
| 913 | 1660 | 38 | 1 | 7 | 0 | 0.4 | 12 | 103 | 1 | 74.5 | 96 | 77.4 |
| 914 | 3100 | 38 | 1 | 8 | 0 | 0.4 | 11 | 108 | 1 | 78.1 | 96 | 81.3 |
| 919 | 165 | 146 | 0 | 7 | 0 | 0.3 | 9 | 99 | 0 | 82.9 | 102 | 81.2 |
| 920 | 1605 | 146 | 0 | 9 | 0 | 0.3 | 9 | 104 | 0 | 79.6 | 102 | 78.0 |
| 921 | 3045 | 146 | 0 | 9 | 0 | 0.3 | 9 | 104 | 0 | 78.6 | 102 | 77.0 |
| 919 | 285 | 35 | 0 | 7 | 0 | 0.3 | 6 | 106 | 1 | 77.1 | 96 | 79.8 |
| 920 | 1725 | 35 | 0 | 9 | 0 | 0.3 | 5 | 107 | 1 | 76.9 | 96 | 79.6 |
| 921 | 3165 | 35 | 0 | 9 | 0 | 0.3 | 5 | 108 | 1 | 75.6 | 96 | 78.2 |
| 919 | 240 | 56 | 0 | 7 | 0 | 0.3 | 15 | 100 | 0 | 71.4 | 92 | 77.5 |
| 920 | 1680 | 56 | 0 | 9 | 0 | 0.3 | 14 | 101 | 0 | 74.6 | 92 | 81.0 |
| 921 | 3120 | 56 | 0 | 9 | 0 | 0.3 | 14 | 99 | 0 | 70.7 | 92 | 76.8 |
| 919 | 225 | 40 | 0 | 7 | 0 | 0.6 | 5 | 98 | 1 | 79.4 | 99 | 79.9 |
| 920 | 1665 | 40 | 0 | 9 | 0 | 0.6 | 5 | 102 | 1 | 74.3 | 99 | 74.8 |
| 921 | 3105 | 40 | 0 | 9 | 0 | 0.6 | 5 | 98 | 1 | 75.6 | 99 | 76.1 |
| 919 | 223 | 43 | 1 | 7 | 0 | 0.3 | 4 | 103 | 1 | 76.9 | 96 | 80.0 |
| 920 | 1663 | 43 | 1 | 9 | 0 | 0.3 | 4 | 108 | 1 | 78.6 | 96 | 81.7 |
| 921 | 3103 | 43 | 1 | 9 | 0 | 0.3 | 4 | 105 | 1 | 80.7 | 96 | 84.0 |
| 919 | 135 | 115 | 0 | 7 | 0 | 0.6 | 5 | 101 | 1 | 77.5 | 95 | 80.9 |
| 920 | 1575 | 115 | 0 | 9 | 0 | 0.6 | 5 | 102 | 1 | 76.0 | 95 | 79.4 |
| 921 | 3015 | 115 | 0 | 9 | 0 | 0.6 | 5 | 102 | 1 | 74.0 | 95 | 77.3 |

Appendix G (cont'd)

| A | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | B | $X_7$ | $X_8$ | C | $X_9$ | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 919 | 195 | 32 | 0 | 7 | 0 | 0.9 | 4 | 105 | 0 | 77.3 | 94 | 82.0 |
| 920 | 1635 | 32 | 0 | 9 | 0 | 0.9 | 4 | 106 | 0 | 74.3 | 94 | 78.7 |
| 921 | 3075 | 32 | 0 | 9 | 0 | 0.9 | 4 | 105 | 0 | 74.2 | 94 | 78.6 |
| 919 | 155 | 25 | 0 | 7 | 0 | 0.3 | 4 | 99 | 0 | 73.0 | 91 | 79.7 |
| 920 | 1595 | 25 | 0 | 9 | 0 | 0.3 | 4 | 103 | 0 | 71.0 | 91 | 77.5 |
| 921 | 3035 | 25 | 0 | 9 | 0 | 0.3 | 4 | 100 | 0 | 69.7 | 91 | 76.1 |
| 926 | 85 | 146 | 0 | 8 | 0 | 0.3 | 9 | 103 | 0 | 79.0 | 94 | 83.8 |
| 927 | 1525 | 146 | 0 | 9 | 0 | 0.3 | 9 | 101 | 0 | 75.5 | 94 | 80.0 |
| 928 | 2965 | 146 | 0 | 9 | 0 | 0.3 | 9 | 103 | 0 | 76.4 | 94 | 81.0 |
| 926 | 350 | 43 | 1 | 8 | 0 | 0.3 | 5 | 100 | 1 | 83.9 | 97 | 86.4 |
| 927 | 1790 | 43 | 1 | 9 | 0 | 0.3 | 4 | 103 | 1 | 83.1 | 97 | 85.6 |
| 928 | 3230 | 43 | 1 | 9 | 0 | 0.3 | 4 | 104 | 1 | 82.0 | 97 | 84.5 |
| 926 | 160 | 41 | 0 | 8 | 0 | 0.3 | 15 | 104 | 1 | 72.9 | 86 | 84.1 |
| 927 | 1600 | 41 | 0 | 9 | 0 | 0.3 | 14 | 101 | 1 | 68.2 | 86 | 78.7 |
| 928 | 3040 | 41 | 0 | 9 | 0 | 0.3 | 14 | 103 | 1 | 67.1 | 86 | 77.4 |
| 926 | 175 | 25 | 0 | 8 | 0 | 0.3 | 5 | 103 | 0 | 74.7 | 93 | 79.9 |
| 927 | 1615 | 25 | 0 | 9 | 0 | 0.3 | 5 | 104 | 0 | 76.0 | 93 | 81.4 |
| 928 | 3055 | 25 | 0 | 9 | 0 | 0.3 | 5 | 103 | 0 | 71.8 | 93 | 76.8 |
| 926 | 281 | 40 | 0 | 8 | 0 | 0.3 | 16 | 102 | 1 | 79.8 | 97 | 82.2 |
| 927 | 1721 | 40 | 0 | 9 | 0 | 0.3 | 16 | 103 | 1 | 77.1 | 97 | 79.5 |
| 928 | 3161 | 40 | 0 | 9 | 0 | 0.3 | 16 | 101 | 1 | 75.5 | 97 | 77.8 |
| 926 | 185 | 35 | 0 | 8 | 0 | 0.3 | 6 | 103 | 1 | 80.4 | 98 | 81.3 |
| 927 | 1625 | 35 | 0 | 9 | 0 | 0.3 | 5 | 105 | 1 | 78.0 | 98 | 78.9 |
| 928 | 3065 | 35 | 0 | 9 | 0 | 0.3 | 5 | 106 | 1 | 76.9 | 98 | 77.8 |
| 926 | 200 | 28 | 0 | 8 | 0 | 0.2 | 10 | 105 | 1 | 79.8 | 99 | 80.3 |
| 927 | 1640 | 28 | 0 | 9 | 0 | 0.2 | 10 | 104 | 1 | 79.3 | 99 | 79.8 |
| 928 | 3080 | 28 | 0 | 9 | 0 | 0.2 | 10 | 107 | 1 | 79.9 | 99 | 80.4 |
| 1003 | 180 | 128 | 0 | 9 | 0 | 0.4 | 11 | 105 | 1 | 74.4 | 92 | 80.0 |
| 1004 | 1620 | 128 | 0 | 8 | 0 | 0.4 | 11 | 105 | 1 | 74.0 | 93 | 79.2 |
| 1005 | 3060 | 128 | 0 | 7 | 0 | 0.4 | 11 | 103 | 1 | 73.4 | 93 | 78.6 |
| 1003 | 150 | 32 | 0 | 9 | 0 | 0.2 | 9 | 105 | 0 | 76.6 | 96 | 79.3 |
| 1004 | 1590 | 32 | 0 | 8 | 0 | 0.2 | 9 | 105 | 0 | 78.9 | 98 | 80.1 |
| 1005 | 3030 | 32 | 0 | 7 | 0 | 0.2 | 8 | 107 | 0 | 76.5 | 101 | 75.7 |
| 1003 | 215 | 38 | 0 | 9 | 0 | 0.3 | 12 | 102 | 1 | 78.5 | 97 | 80.5 |
| 1004 | 1655 | 38 | 0 | 8 | 0 | 0.3 | 12 | 104 | 1 | 76.7 | 97 | 78.7 |
| 1005 | 3095 | 38 | 0 | 7 | 0 | 0.3 | 12 | 101 | 1 | 75.3 | 97 | 77.6 |
| 1003 | 262 | 25 | 0 | 9 | 0 | 0.3 | 15 | 104 | 0 | 73.4 | 89 | 81.8 |
| 1004 | 1702 | 25 | 0 | 8 | 0 | 0.3 | 15 | 103 | 0 | 70.1 | 86 | 81.3 |
| 1005 | 3142 | 25 | 0 | 7 | 0 | 0.3 | 15 | 101 | 0 | 67.7 | 86 | 78.5 |
| 1003 | 220 | 40 | 0 | 9 | 0 | 0.4 | 10 | 98 | 1 | 87.7 | 108 | 80.9 |
| 1004 | 1660 | 40 | 0 | 8 | 0 | 0.4 | 9 | 95 | 1 | 89.6 | 110 | 81.3 |
| 1005 | 3100 | 40 | 0 | 7 | 0 | 0.4 | 9 | 99 | 1 | 80.7 | 102 | 78.8 |
| 1003 | 190 | 43 | 0 | 9 | 0 | 0.3 | 5 | 103 | 1 | 85.5 | 107 | 79.8 |
| 1004 | 1630 | 43 | 0 | 8 | 0 | 0.3 | 5 | 100 | 1 | 86.7 | 108 | 80.0 |
| 1005 | 3070 | 43 | 0 | 7 | 0 | 0.3 | 4 | 101 | 1 | 80.4 | 106 | 75.7 |
| 1010 | 55 | 35 | 0 | 8 | 0 | 0.3 | 5 | 109 | 1 | 79.4 | 98 | 80.3 |
| 1011 | 1435 | 35 | 0 | 7 | 0 | 0.3 | 5 | 104 | 1 | 73.8 | 93 | 78.6 |
| 1012 | 2875 | 35 | 0 | 6 | 0 | 0.3 | 5 | 105 | 1 | 75.4 | 96 | 78.0 |

Appendix G (cont'd)

| A | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | B | $X_7$ | $X_8$ | C | $X_9$ | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1010 | 252 | 19 | 0 | 8 | 0 | 0.5 | 10 | 104 | 1 | 80.9 | 101 | 80.0 |
| 1011 | 1692 | 19 | 0 | 7 | 0 | 0.5 | 10 | 105 | 1 | 77.0 | 96 | 79.7 |
| 1012 | 3132 | 19 | 0 | 6 | 0 | 0.5 | 11 | 104 | 1 | 78.1 | 98 | 79.0 |
| 1010 | 235 | 96 | 0 | 8 | 0 | 0.3 | 13 | 103 | 1 | 70.8 | 88 | 80.0 |
| 1011 | 1675 | 96 | 0 | 7 | 0 | 0.3 | 12 | 102 | 1 | 71.3 | 89 | 79.3 |
| 1012 | 3115 | 96 | 0 | 6 | 0 | 0.3 | 12 | 102 | 1 | 70.7 | 89 | 78.7 |
| 1010 | 180 | 43 | 1 | 8 | 0 | 0.3 | 5 | 105 | 1 | 81.2 | 101 | 80.3 |
| 1011 | 1620 | 43 | 1 | 7 | 0 | 0.3 | 4 | 101 | 1 | 83.8 | 106 | 79.0 |
| 1012 | 3060 | 43 | 1 | 6 | 0 | 0.3 | 4 | 106 | 1 | 78.1 | 100 | 77.9 |
| 1010 | 165 | 28 | 0 | 8 | 0 | 0.3 | 10 | 106 | 1 | 81.5 | 101 | 80.5 |
| 1011 | 1605 | 28 | 0 | 7 | 0 | 0.3 | 10 | 105 | 1 | 81.0 | 100 | 80.4 |
| 1012 | 3045 | 28 | 0 | 6 | 0 | 0.3 | 11 | 103 | 1 | 80.6 | 102 | 78.3 |
| 1010 | 180 | 25 | 0 | 8 | 0 | 0.3 | 4 | 100 | 0 | 61.2 | 77 | 78.9 |
| 1011 | 1620 | 25 | 0 | 7 | 0 | 0.3 | 4 | 103 | 0 | 62.1 | 77 | 80.1 |
| 1012 | 3060 | 25 | 0 | 6 | 0 | 0.3 | 4 | 99 | 0 | 62.6 | 79 | 78.4 |
| 1010 | 180 | 96 | 0 | 8 | 0 | 0.3 | 13 | 103 | 1 | 74.6 | 93 | 79.5 |
| 1011 | 1620 | 96 | 0 | 7 | 0 | 0.3 | 13 | 103 | 1 | 74.6 | 93 | 79.4 |
| 1012 | 3060 | 96 | 0 | 6 | 0 | 0.3 | 13 | 101 | 1 | 76.9 | 97 | 78.5 |
| 1017 | 165 | 24 | 0 | 8 | 0 | 0.4 | 9 | 105 | 1 | 79.0 | 99 | 79.2 |
| 1018 | 1605 | 24 | 0 | 11 | 0 | 0.4 | 8 | 106 | 1 | 75.5 | 97 | 77.4 |
| 1019 | 3045 | 24 | 0 | 11 | 0 | 0.4 | 8 | 105 | 1 | 77.6 | 98 | 78.4 |
| 1017 | 110 | 40 | 0 | 8 | 0 | 0.3 | 22 | 102 | 1 | 81.2 | 99 | 81.7 |
| 1018 | 1550 | 40 | 0 | 11 | 0 | 0.3 | 22 | 103 | 1 | 80.1 | 100 | 79.9 |
| 1019 | 2990 | 40 | 0 | 11 | 0 | 0.3 | 20 | 102 | 1 | 80.2 | 100 | 80.0 |
| 1017 | 153 | 43 | 0 | 8 | 0 | 0.3 | 5 | 102 | 1 | 85.7 | 107 | 79.7 |
| 1018 | 1593 | 43 | 0 | 11 | 0 | 0.3 | 4 | 107 | 1 | 84.3 | 108 | 77.7 |
| 1019 | 3033 | 43 | 0 | 11 | 0 | 0.3 | 4 | 105 | 1 | 80.5 | 104 | 77.2 |
| 1017 | 160 | 40 | 0 | 8 | 0 | 0.6 | 6 | 101 | 0 | 83.8 | 101 | 82.5 |
| 1018 | 1600 | 40 | 0 | 11 | 0 | 0.6 | 6 | 104 | 0 | 79.2 | 98 | 80.0 |
| 1019 | 3040 | 40 | 0 | 11 | 0 | 0.6 | 6 | 103 | 0 | 82.6 | 103 | 79.9 |
| 1017 | 145 | 128 | 0 | 8 | 0 | 0.6 | 10 | 103 | 1 | 87.8 | 108 | 80.7 |
| 1018 | 1585 | 128 | 0 | 11 | 0 | 0.6 | 9 | 106 | 1 | 82.4 | 103 | 79.7 |
| 1019 | 3025 | 128 | 0 | 11 | 0 | 0.6 | 9 | 104 | 1 | 87.9 | 113 | 77.2 |
| 1017 | 130 | 32 | 0 | 8 | 0 | 0.7 | 5 | 103 | 0 | 77.7 | 98 | 79.0 |
| 1018 | 1570 | 32 | 0 | 11 | 0 | 0.7 | 5 | 104 | 0 | 75.7 | 95 | 79.1 |
| 1019 | 3010 | 32 | 0 | 11 | 0 | 0.7 | 5 | 102 | 0 | 70.3 | 93 | 75.2 |
| 1017 | 180 | 38 | 0 | 8 | 0 | 0.3 | 12 | 103 | 1 | 81.8 | 100 | 81.2 |
| 1018 | 1620 | 38 | 0 | 11 | 0 | 0.3 | 12 | 103 | 1 | 78.9 | 99 | 79.1 |
| 1019 | 3060 | 38 | 0 | 11 | 0 | 0.3 | 12 | 104 | 1 | 76.0 | 96 | 78.7 |
| 1024 | 165 | 43 | 0 | 4 | 0 | 0.3 | 5 | 99 | 1 | 83.8 | 104 | 80.0 |
| 1025 | 1605 | 43 | 0 | 5 | 0 | 0.3 | 4 | 102 | 1 | 83.7 | 104 | 80.2 |
| 1026 | 3045 | 43 | 0 | 4 | 0 | 0.3 | 4 | 103 | 1 | 83.1 | 106 | 78.0 |
| 1024 | 175 | 32 | 0 | 4 | 0 | 0.6 | 7 | 107 | 0 | 74.9 | 94 | 79.4 |
| 1025 | 1615 | 32 | 0 | 5 | 0 | 0.6 | 6 | 106 | 0 | 71.7 | 92 | 77.9 |
| 1026 | 3055 | 32 | 0 | 4 | 0 | 0.6 | 6 | 106 | 0 | 73.4 | 92 | 79.7 |
| 1024 | 280 | 28 | 1 | 4 | 0 | 0.4 | 8 | 102 | 1 | 86.5 | 106 | 81.5 |
| 1025 | 1720 | 28 | 1 | 5 | 0 | 0.4 | 8 | 104 | 1 | 83.3 | 103 | 80.2 |
| 1026 | 3160 | 28 | 1 | 4 | 0 | 0.4 | 7 | 104 | 1 | 81.9 | 104 | 78.5 |

Appendix G (cont'd)

| A | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | B | $X_7$ | $X_8$ | C | $X_9$ | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1024 | 220 | 51 | 0 | 4 | 0 | 0.4 | 10 | 105 | 0 | 75.3 | 93 | 80.6 |
| 1025 | 1660 | 51 | 0 | 5 | 0 | 0.4 | 10 | 106 | 0 | 75.7 | 95 | 79.5 |
| 1026 | 3100 | 51 | 0 | 4 | 0 | 0.4 | 10 | 104 | 0 | 73.3 | 93 | 78.0 |
| 1024 | 250 | 45 | 0 | 4 | 0 | 0.5 | 9 | 93 | 1 | 101.7 | 121 | 83.7 |
| 1025 | 1690 | 45 | 0 | 5 | 0 | 0.5 | 9 | 94 | 1 | 101.5 | 126 | 80.2 |
| 1026 | 3130 | 45 | 0 | 4 | 0 | 0.5 | 8 | 97 | 1 | 99.9 | 124 | 80.4 |
| 1024 | 260 | 24 | 0 | 4 | 0 | 0.3 | 9 | 102 | 1 | 83.4 | 101 | 82.1 |
| 1025 | 1700 | 24 | 0 | 5 | 0 | 0.3 | 9 | 99 | 1 | 84.0 | 103 | 80.8 |
| 1026 | 3140 | 24 | 0 | 4 | 0 | 0.3 | 8 | 102 | 1 | 86.8 | 108 | 80.1 |
| 1024 | 195 | 51 | 0 | 4 | 0 | 0.3 | 12 | 103 | 1 | 79.8 | 100 | 79.6 |
| 1025 | 1635 | 51 | 0 | 5 | 0 | 0.3 | 11 | 103 | 1 | 79.1 | 101 | 78.2 |
| 1026 | 3075 | 51 | 0 | 4 | 0 | 0.3 | 11 | 102 | 1 | 79.9 | 102 | 78.3 |
| 1024 | 265 | 25 | 0 | 4 | 0 | 0.3 | 15 | 103 | 1 | 81.9 | 99 | 82.4 |
| 1025 | 1705 | 25 | 0 | 5 | 0 | 0.3 | 15 | 105 | 1 | 77.4 | 97 | 79.4 |
| 1026 | 3145 | 25 | 0 | 4 | 0 | 0.3 | 14 | 104 | 1 | 78.9 | 99 | 79.5 |
| 1031 | 150 | 25 | 0 | 5 | 1 | 0.3 | 15 | 102 | 0 | 71.8 | 86 | 83.3 |
| 1101 | 1590 | 25 | 0 | 8 | 1 | 0.3 | 15 | 103 | 0 | 71.2 | 88 | 80.1 |
| 1102 | 3030 | 25 | 0 | 8 | 1 | 0.3 | 15 | 102 | 0 | 69.9 | 88 | 79.1 |
| 1031 | 155 | 28 | 0 | 5 | 1 | 0.3 | 12 | 105 | 1 | 79.4 | 98 | 80.3 |
| 1101 | 1595 | 28 | 0 | 8 | 1 | 0.3 | 10 | 105 | 1 | 80.1 | 100 | 79.5 |
| 1102 | 3035 | 28 | 0 | 8 | 1 | 0.3 | 10 | 103 | 1 | 78.6 | 101 | 77.3 |
| 1031 | 180 | 32 | 0 | 5 | 1 | 0.5 | 7 | 104 | 0 | 75.3 | 94 | 79.8 |
| 1101 | 1620 | 32 | 0 | 8 | 1 | 0.5 | 7 | 104 | 0 | 73.4 | 93 | 78.6 |
| 1102 | 3060 | 32 | 0 | 8 | 1 | 0.5 | 6 | 103 | 0 | 72.3 | 94 | 76.2 |
| 1031 | 165 | 43 | 0 | 5 | 1 | 0.3 | 5 | 98 | 1 | 83.3 | 107 | 77.5 |
| 1101 | 1605 | 43 | 0 | 8 | 1 | 0.3 | 4 | 100 | 1 | 86.1 | 109 | 78.7 |
| 1102 | 3045 | 43 | 0 | 8 | 1 | 0.3 | 4 | 106 | 1 | 80.2 | 104 | 76.5 |
| 1031 | 180 | 96 | 0 | 5 | 1 | 0.3 | 14 | 100 | 1 | 73.0 | 92 | 78.9 |
| 1101 | 1620 | 96 | 0 | 8 | 1 | 0.3 | 13 | 103 | 1 | 67.9 | 86 | 78.3 |
| 1102 | 3060 | 96 | 0 | 8 | 1 | 0.3 | 13 | 101 | 1 | 67.0 | 87 | 76.6 |
| 1031 | 160 | 128 | 0 | 5 | 1 | 0.5 | 9 | 106 | 1 | 77.8 | 97 | 79.4 |
| 1101 | 1600 | 128 | 0 | 8 | 1 | 0.5 | 9 | 104 | 1 | 78.7 | 98 | 79.6 |
| 1102 | 3040 | 128 | 0 | 8 | 1 | 0.5 | 8 | 104 | 1 | 75.9 | 97 | 77.4 |
| 1107 | 120 | 48 | 0 | 6 | 1 | 0.4 | 7 | 100 | 1 | 84.7 | 104 | 80.8 |
| 1108 | 1560 | 48 | 0 | 2 | 1 | 0.4 | 7 | 98 | 1 | 82.9 | 104 | 79.1 |
| 1109 | 3000 | 48 | 0 | -1 | 1 | 0.4 | 7 | 100 | 1 | 78.3 | 97 | 80.0 |
| 1107 | 100 | 48 | 0 | 6 | 1 | 0.3 | 12 | 101 | 1 | 70.2 | 87 | 80.2 |
| 1108 | 1540 | 48 | 0 | 2 | 1 | 0.3 | 11 | 101 | 1 | 74.6 | 92 | 80.6 |
| 1109 | 2980 | 48 | 0 | -1 | 1 | 0.3 | 11 | 100 | 1 | 73.8 | 94 | 78.2 |
| 1107 | 145 | 43 | 0 | 6 | 1 | 0.3 | 4 | 105 | 1 | 83.5 | 103 | 80.3 |
| 1108 | 1585 | 43 | 0 | 2 | 1 | 0.3 | 4 | 101 | 1 | 86.6 | 110 | 78.3 |
| 1109 | 3025 | 43 | 0 | -1 | 1 | 0.3 | 5 | 102 | 1 | 82.7 | 105 | 78.3 |
| 1107 | 195 | 25 | 0 | 6 | 1 | 0.3 | 3 | 101 | 0 | 78.9 | 95 | 82.9 |
| 1108 | 1635 | 25 | 0 | 2 | 1 | 0.3 | 3 | 101 | 0 | 75.4 | 93 | 80.4 |
| 1109 | 3075 | 25 | 0 | -1 | 1 | 0.3 | 2 | 102 | 0 | 73.5 | 94 | 77.9 |
| 1107 | 190 | 51 | 0 | 6 | 1 | 0.8 | 5 | 104 | 0 | 79.0 | 96 | 81.8 |
| 1108 | 1630 | 51 | 0 | 2 | 1 | 0.8 | 5 | 107 | 0 | 78.6 | 97 | 80.9 |
| 1109 | 3070 | 51 | 0 | -1 | 1 | 0.8 | 5 | 105 | 0 | 77.0 | 96 | 80.1 |

Appendix H

SUMMARY TABLE OF THE BEST-FITTING PHASE 1 REGRESSION

| Variable | Std. Error B | Multiple R | R square | Rsq Change | Simple R | B | Beta |
|---|---|---|---|---|---|---|---|
| *Time* | 0.0054 | 0.6116 | 0.3740 | 0.3740 | -0.6116 | -0.0488 | -0.6324 |
| *Fatness* | 0.0434 | 0.6472 | 0.4188 | 0.0448 | -0.2059 | -0.1151 | -0.1970 |
| *Air Temperature* | 0.0423 | 0.6638 | 0.4406 | 0.0218 | -0.1390 | -0.1021 | -0.1884 |
| *Water Availability* | 0.2611 | 0.6772 | 0.4587 | 0.0180 | -0.0465 | -0.4888 | -0.1454 |
| *Handling stress level* | 0.2940 | 0.6865 | 0.4712 | 0.0126 | -0.0685 | -0.2122 | -0.0631 |
| *Distance* | 0.0040 | 0.6885 | 0.4740 | 0.0027 | -0.1279 | -0.0038 | -0.0739 |
| *Density* | 1.0064 | 0.6915 | 0.4781 | 0.0041 | 0.0529 | 0.9160 | 0.0736 |
| *Time Last Fed* | 0.5011 | 0.6917 | 0.4785 | 0.0003 | 00.0227 | 0.1352 | 0.0197 |
| *Constant* | 93.39 | | | | | | |

# Appendix I

## LIST OF DATA USED IN THE PHASE 2 REGRESSION

A = Number of hogs in each load
$X_1$ = Time from assembly to slaughter (hours)
$X_2$ = Distance from farm to plant (km)
$X_3$ = Fatness (index average of a load)
$X_4$ = Liveweight (average liveweight of a load, kg/hog)
Y = Yield (average load carcass weight/average load liveweight)x100

| $X_1$ | $X_2$ | A | Y | $X_3$ | $X_4$ |
|---|---|---|---|---|---|
| 26 | 571 | 12 | 78.44 | 100.67 | 109.58 |
| 26 | 587 | 12 | 80.05 | 99.25 | 102.75 |
| 26 | 595 | 28 | 83.21 | 97.93 | 104.79 |
| 27 | 555 | 65 | 82.03 | 104.06 | 90.57 |
| 27 | 563 | 10 | 79.49 | 103.00 | 100.60 |
| 27 | 531 | 16 | 78.79 | 101.56 | 101.44 |
| 27 | 555 | 75 | 80.67 | 102.35 | 94.35 |
| 27 | 612 | 7 | 79.51 | 97.71 | 97.71 |
| 25 | 555 | 10 | 79.16 | 99.80 | 99.70 |
| 25 | 563 | 10 | 80.81 | 103.40 | 99.30 |
| 26 | 571 | 12 | 79.71 | 99.83 | 113.00 |
| 26 | 531 | 9 | 79.98 | 95.89 | 110.78 |
| 27 | 531 | 7 | 77.39 | 99.71 | 99.14 |
| 27 | 620 | 33 | 89.48 | 100.06 | 93.03 |
| 27 | 531 | 9 | 77.43 | 102.33 | 90.67 |
| 27 | 563 | 31 | 85.51 | 103.52 | 94.94 |
| 27 | 563 | 44 | 79.09 | 105.43 | 94.52 |
| 28 | 528 | 9 | 81.23 | 106.00 | 98.78 |
| 26 | 571 | 10 | 78.37 | 98.10 | 83.40 |
| 26 | 563 | 26 | 79.92 | 103.35 | 99.23 |
| 26 | 531 | 3 | 78.29 | 98.00 | 93.67 |
| 26 | 579 | 78 | 73.34 | 101.95 | 111.18 |
| 26 | 531 | 30 | 80.77 | 102.53 | 88.90 |
| 26 | 620 | 63 | 82.61 | 102.27 | 101.22 |
| 26 | 555 | 35 | 79.27 | 104.83 | 104.71 |
| 26 | 603 | 6 | 73.66 | 99.83 | 79.33 |
| 26 | 571 | 11 | 75.46 | 101.27 | 89.45 |
| 26 | 547 | 39 | 79.34 | 103.49 | 102.79 |
| 26 | 571 | 12 | 80.65 | 99.50 | 113.33 |
| 27 | 563 | 5 | 76.24 | 106.60 | 95.20 |
| 27 | 555 | 9 | 77.47 | 103.67 | 108.78 |
| 27 | 620 | 5 | 76.20 | 100.60 | 90.60 |
| 27 | 563 | 10 | 79.85 | 100.10 | 104.70 |
| 27 | 571 | 2 | 79.02 | 102.00 | 95.00 |
| 27 | 531 | 14 | 77.82 | 103.36 | 100.43 |
| 27 | 555 | 22 | 81.49 | 103.64 | 99.36 |
| 27 | 531 | 12 | 77.80 | 104.83 | 98.58 |

Appendix I (cont'd)

| $X_1$ | $X_2$ | A | Y | $X_3$ | $X_4$ |
|---|---|---|---|---|---|
| 28 | 539 | 2 | 76.66 | 97.50 | 106.50 |
| 28 | 539 | 3 | 72.98 | 103.33 | 98.00 |
| 28 | 539 | 6 | 78.00 | 99.33 | 105.83 |
| 28 | 531 | 11 | 77.80 | 103.36 | 94.82 |
| 28 | 531 | 3 | 80.69 | 102.00 | 104.00 |
| 28 | 555 | 21 | 78.01 | 104.57 | 96.52 |
| 21 | 571 | 4 | 76.62 | 102.75 | 99.75 |
| 21 | 547 | 21 | 79.70 | 102.52 | 99.76 |
| 21 | 571 | 2 | 78.22 | 102.50 | 92.50 |
| 22 | 603 | 13 | 78.70 | 95.77 | 87.92 |
| 22 | 587 | 5 | 79.77 | 101.80 | 105.20 |
| 22 | 528 | 12 | 80.09 | 99.50 | 102.42 |
| 23 | 563 | 30 | 80.10 | 101.97 | 92.67 |
| 23 | 547 | 26 | 84.00 | 97.27 | 105.88 |
| 23 | 547 | 5 | 78.93 | 103.80 | 101.60 |
| 23 | 531 | 14 | 77.56 | 99.71 | 99.43 |
| 23 | 636 | 35 | 82.12 | 100.51 | 103.66 |
| 23 | 555 | 1 | 83.85 | 107.00 | 99.00 |
| 23 | 563 | 44 | 82.72 | 103.23 | 98.43 |
| 24 | 534 | 4 | 77.85 | 102.00 | 107.50 |
| 24 | 523 | 3 | 82.09 | 92.33 | 110.33 |
| 21 | 666 | 8 | 81.96 | 102.25 | 95.75 |
| 26 | 636 | 6 | 79.30 | 104.50 | 96.00 |
| 26 | 525 | 5 | 77.21 | 96.40 | 108.80 |
| 27 | 612 | 71 | 86.21 | 102.08 | 98.18 |
| 27 | 620 | 33 | 86.31 | 101.58 | 93.45 |
| 27 | 563 | 28 | 80.65 | 103.39 | 94.93 |
| 27 | 571 | 50 | 78.24 | 101.60 | 85.26 |
| 28 | 563 | 35 | 79.68 | 103.23 | 94.60 |
| 27 | 555 | 4 | 78.17 | 99.75 | 107.50 |
| 26 | 563 | 10 | 78.89 | 102.00 | 101.60 |
| 26 | 547 | 43 | 79.08 | 101.86 | 98.09 |
| 26 | 517 | 2 | 75.60 | 102.00 | 111.00 |
| 25 | 587 | 6 | 77.82 | 98.00 | 99.67 |
| 25 | 612 | 2 | 81.52 | 95.50 | 108.50 |
| 25 | 563 | 10 | 81.53 | 102.20 | 94.30 |
| 25 | 612 | 10 | 74.81 | 99.40 | 107.50 |
| 25 | 555 | 10 | 80.34 | 100.60 | 98.80 |
| 25 | 547 | 15 | 80.27 | 101.13 | 95.80 |
| 25 | 620 | 4 | 76.46 | 100.00 | 96.25 |
| 25 | 563 | 4 | 81.49 | 101.25 | 100.75 |
| 25 | 587 | 12 | 79.23 | 99.75 | 96.75 |
| 24 | 518 | 15 | 80.75 | 101.00 | 92.20 |
| 24 | 547 | 11 | 76.48 | 99.18 | 92.36 |
| 24 | 531 | 8 | 77.55 | 97.63 | 109.38 |
| 24 | 555 | 31 | 83.78 | 101.39 | 95.68 |
| 24 | 518 | 15 | 80.72 | 100.47 | 94.93 |
| 24 | 563 | 10 | 76.59 | 104.20 | 105.60 |
| 27 | 628 | 33 | 84.15 | 104.52 | 89.33 |
| 28 | 563 | 10 | 77.50 | 103.00 | 91.60 |

Appendix I (cont'd)

| $X_1$ | $X_2$ | A | Y | $X_3$ | $X_4$ |
|---|---|---|---|---|---|
| 28 | 555 | 44 | 80.73 | 104.36 | 99.57 |
| 28 | 571 | 35 | 79.32 | 104.77 | 95.37 |
| 29 | 531 | 7 | 80.99 | 103.71 | 95.86 |
| 29 | 555 | 40 | 80.08 | 105.07 | 95.57 |
| 24 | 346 | 44 | 79.60 | 107.05 | 96.64 |
| 23 | 335 | 14 | 79.08 | 105.07 | 95.71 |
| 23 | 515 | 31 | 79.72 | 103.26 | 87.68 |
| 22 | 378 | 30 | 79.75 | 102.93 | 105.17 |
| 21 | 330 | 9 | 79.10 | 104.22 | 99.78 |
| 21 | 362 | 20 | 78.79 | 103.10 | 92.95 |
| 20 | 362 | 18 | 78.38 | 104.44 | 96.83 |
| 21 | 338 | 15 | 79.52 | 104.00 | 92.33 |
| 22 | 327 | 12 | 78.08 | 101.75 | 87.33 |
| 21 | 327 | 12 | 79.05 | 100.17 | 86.17 |
| 21 | 351 | 8 | 78.35 | 102.13 | 95.38 |
| 20 | 515 | 37 | 79.83 | 102.00 | 91.41 |
| 20 | 410 | 26 | 80.56 | 103.81 | 83.96 |
| 19 | 362 | 19 | 80.89 | 100.79 | 95.47 |
| 18 | 381 | 30 | 79.01 | 104.60 | 102.50 |
| 26 | 475 | 27 | 64.71 | 98.07 | 91.70 |
| 26 | 370 | 14 | 78.45 | 102.07 | 95.57 |
| 26 | 330 | 29 | 78.73 | 102.38 | 97.34 |
| 26 | 426 | 52 | 80.66 | 104.50 | 93.56 |
| 27 | 386 | 12 | 79.44 | 100.83 | 96.50 |
| 27 | 459 | 33 | 80.53 | 102.82 | 89.55 |
| 25 | 354 | 7 | 76.20 | 101.71 | 90.57 |
| 25 | 348 | 30 | 78.28 | 103.73 | 99.80 |
| 26 | 451 | 41 | 79.28 | 102.78 | 98.93 |
| 25 | 354 | 18 | 77.65 | 102.78 | 87.72 |
| 25 | 393 | 3 | 77.01 | 104.67 | 103.67 |
| 25 | 351 | 8 | 80.74 | 105.13 | 97.13 |
| 24 | 346 | 3 | 81.01 | 88.67 | 137.00 |
| 23 | 426 | 23 | 76.90 | 102.22 | 96.61 |
| 24 | 201 | 23 | 78.04 | 96.35 | 88.04 |
| 24 | 257 | 10 | 80.05 | 99.80 | 107.60 |
| 24 | 185 | 14 | 80.98 | 99.93 | 99.79 |
| 25 | 241 | 10 | 76.32 | 97.20 | 98.90 |
| 23 | 180 | 8 | 77.83 | 103.88 | 104.25 |
| 24 | 233 | 49 | 80.31 | 103.35 | 97.78 |
| 24 | 298 | 36 | 79.39 | 99.94 | 84.19 |
| 24 | 188 | 25 | 79.12 | 100.20 | 97.72 |
| 27 | 193 | 1 | 82.78 | 91.00 | 120.00 |
| 27 | 185 | 7 | 78.33 | 101.71 | 83.14 |
| 26 | 257 | 30 | 82.51 | 102.53 | 92.03 |
| 25 | 266 | 32 | 82.33 | 104.88 | 95.16 |
| 24 | 249 | 21 | 80.15 | 100.29 | 87.48 |
| 24 | 180 | 31 | 79.36 | 102.42 | 87.32 |
| 24 | 190 | 21 | 79.39 | 102.10 | 92.43 |
| 24 | 217 | 30 | 78.98 | 102.80 | 84.37 |

# Appendix J

## SUMMARY TABLE OF THE PHASE 2 REGRESSION

| Variable | Std. Error B | Multiple R | R Square | Rsq Change | Simple R | B | Beta |
|---|---|---|---|---|---|---|---|
| *Distance* | 0.0020 | 0.0675 | 0.0046 | 0.0046 | 0.0675 | 0.0015 | 0.0710 |
| *Liveweight* | 0.0328 | 0.0805 | 0.0065 | 0.0019 | 0.0525 | 0.0237 | 0.0688 |
| *Fatness* | 0.0887 | 0.0968 | 0.0094 | 0.0029 | 0.0336 | 0.0560 | 0.0595 |
| *Time* | 0.1112 | 0.1053 | 0.0111 | 0.0017 | -0.0155 | -0.0530 | -0.0436 |